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JOURNAL OF PALEONTOLOGY

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CONTENTS

The siphuncle of late Paleozoic ammonoids ..... *A. K. Miller and A. G. Unklesbay* 1

The discovery of fossil vertebrates in North America ..... *George Gaylord Simpson* 26

Strophomenacea of the Cedar Valley limestone of Iowa ..... *Merrill A. Stainbrook* 39

Acila princeps, a new Upper Cretaceous pelecypod from California ..... *Hubert G. Schenck* 60

Marine invertebrate faunas of the buried beaches near Nome, Alaska ..... *F. Stearns MacNeil, John B. Mertie, Jr., and Henry A. Pilsbry* 69

A restudy of the foraminiferal genera *Pseudorbitoides* and *Vaughanina* ..... *Thomas Wayland Vaughan and W. Storrs Cole* 97

New Lower Ordovician trilobites from Levis, Quebec ..... *Franco Rasetti* 101

Some unusual cystoids and crinoids from the Niagaran (Silurian) of west central Ohio ..... *Daniel A. Busch* 105

Pleistocene horse teeth from Saskatchewan ..... *Loris S. Russell* 110

Lower Tertiary *Aturia* from Palestine ..... *Moshè Avnimelech* 115

Pleistocene mollusks from Margarita Island, Venezuela ..... *Horace G. Richards* 120

PALEONTOLOGICAL NOTES

List of the fossil birds of New Jersey ..... *William F. Rapp, Jr.* 124

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VOLUME 17 JANUARY, 1943 NUMBER 1

THE SIPHUNCLE OF LATE PALEOZOIC AMMONOIDS

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ABSTRACT—Representatives of most of the families of Late Paleozoic ammonoids were studied in median dorsoventral sections. The ontogenetic development of the siphuncle and other internal structures is described and illustrated in as much detail as the available material will permit. It is concluded that the siphuncular structures do not have as much taxonomic value as do the sutures, and there seems to be no definite relationship between the development of complexity in the siphuncle and in the sutures.

MANY CONTRIBUTIONS have been made to our knowledge of the development of the ammonoid siphuncle, and of particular merit are the works of Hyatt, Munier-Chalmas, Branco, Smith, Grandjean, Schoulga-Nesterenko, Schindewolf, Spath, and Böhmers. A wealth of well-preserved specimens from the Permian of Timor was available to the last of these authors, Böhmers, and his results are accordingly transcendent—unfortunately, however, his study was issued as a private publication and is therefore not readily available.

One of the difficulties encountered in a study of this type is the fact that only exceptionally well preserved specimens make satisfactory thin sections. Therefore many specimens have to be sacrificed to obtain a few good sections. The material on which the present report is based was assembled over a period of several years. Much of the best of it came from the John Britts Owen collection, which is now at the State University of Iowa. G. A. Cooper of the United States National Museum supplied a small collection of Devonian forms from Michigan, and J. S. Williams of the United States Geological Survey loaned representatives of certain rare genera from the Permian of Texas. Most of the Russian specimens, which are particularly well preserved, were collected by the senior author during the excursions of the Seventeenth International Geological Congress in 1937, and in the previous year he and W. M. Furnish collected the Mexican material. Acknowledgment is due to Howard Webster for retouching the photographs and inking the drawings which accompany this report.

The terminology that has been employed by different investigators has of course varied considerably, and the variation is emphasized by the fact that their results have been published in several languages Essentially all of the terms used in the present report are English equivalents of those used previously. These terms are elucidated by text figure 1, but it should be kept in mind that this illustration portrays structures only as they are seen in thin sections and is therefore two-dimensional. Definite information is lacking in regard to the third dimension of certain features like the prosiphon. Grandjean regarded that structure as being band-shaped. Schoulga-Nesterenko thought it to be infundibuliform, but the present investigation has led to the belief that in at least the Late Paleo-

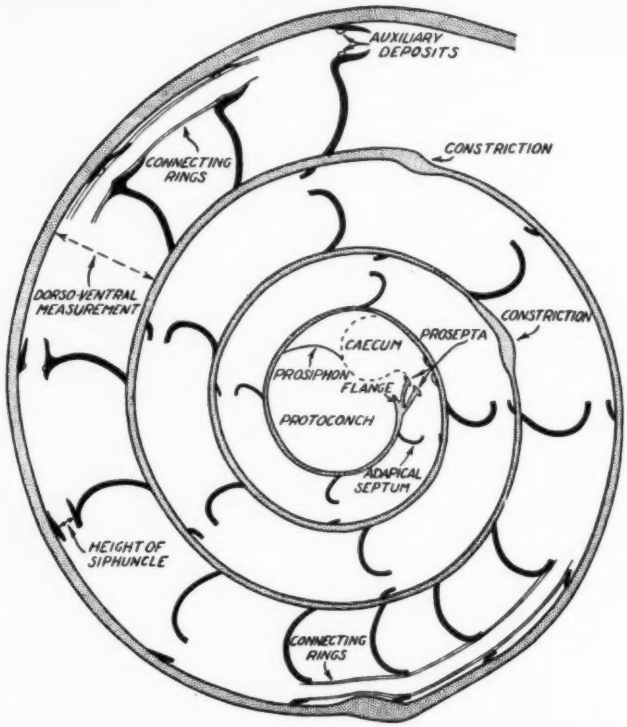

FIG. *1*—Enlarged median dorsoventral section of the adapical portion of the shell of a typical ammonoid, showing diagrammatically the various internal structures.

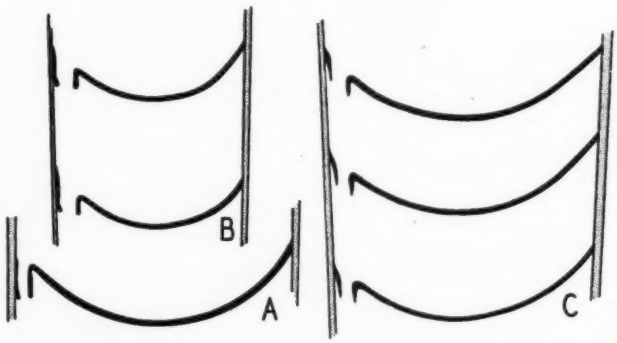

FIG. *2*—Median dorsoventral sections of typical Pennsylvanian, Mississippian, and Devonian representatives of *Bactrites*, all ×10. *A*, From the Cherokee shale of Henry County, Missouri; *B*, from the Caney shale of Oklahoma; *C*, from the Antrim formation at Partridge Point, Michigan (State Univ. Iowa, 1682, 1680, and 1678).

zoic forms it has the shape of a partial cone (see pl. 1, fig. 5). In dorsoventral sections that are not quite median, the prosiphon appears as a short line extending obliquely from the caecum to the wall of the protoconch. As the section approaches the median

plane, this line migrates dorsad, and its point of attachment to the protoconch migrates apicad.

The caecum, which lies between the prosiphon and the siphuncle proper, is a subspherical bulbous structure which has very thin walls and in many cases is not preserved. In some forms, like *Goniolobоceras* (text fig. 5A), there is a secondary expansion of the caecum between the prosepta, which are rather far apart. As a general rule the prosepta are considerably thicker than the adapical septa, and they appear to be continuous with the spiral shell wall, rather than cemented to it as are the septa. Where they are in contact with the caecum-siphuncle, the prosepta are considerably enlarged. The flange, which is an adapical extension of the shell wall, is short, and the angle between it and the posterior proseptum is quite variable.

The siphuncle of most of the Late Paleozoic ammonoids is ventral and marginal in position throughout ontogenetic development. However, in *Agathiceras* it is subcentral in the early volutions of the phragmacone and migrates to the ventral margin of the conch rather gradually. It seems very doubtful if any great significance should be attributed to the fact that in this genus the siphuncle is at first far removed from the margin of the conch, particularly since Spath and later Schindewolf have stated that in certain Carboniferous ammonoids like *Dimorphoceras* the siphuncle is not invariably marginal in the extreme adapical portion of the phragmacone.

During at least early growth stages, the septal necks of all Paleozoic ammonoids are retrosiphonate. In many of the more advanced forms (but not in such discoidal ones as the pronoritids, medlicottids, and daraelitids) the septal necks soon develop adoral projections and eventually become prosiphonate. In some forms the change from one condition to the other is gradual but in others it takes place in less than one-fourth of a volution (pl. 2, fig. 5). Most of the prosiphonate forms develop auxiliary deposits on the inside of the septal necks. In well-preserved thin sections the line of demarcation between the secondary deposits and the septal necks proper is readily discernible. In a few forms these auxiliary deposits seem to consist of simple rings, but in others they are relatively complex and are composed of several parts. The connecting rings are attached to the auxiliary deposits when they are present. In some cases the connecting rings are continuous through the septal necks, but in others they are not (text figs. 6E, F). The connecting rings seem to be continuous with the walls of the caecum (text fig. 5A), and in some sections there are preserved what appear to be longitudinal fibers that were arranged in more or less of a spiral fashion in the walls of the connecting rings (pl. 2, fig. 4). In *Agathiceras* the connecting rings are especially short and merely serve to bridge the gaps between the exceedingly long septal necks. *Agathiceras* is one of the few genera of Permian ammonoids that can be readily recognized in median dorsoventral sections —it is characterized by a subcentral siphuncle during early growth stages and long septal necks at maturity.

In all of the thin sections in which the inner whorls are preserved, the ventral portion of the conch is modified near the adoral end of the first volution. In some cases this modification takes the form of a constriction, whereas in others it is an expansion—generally it is rather prominent. It seems likely that this feature is analogous to the so-called nepionic line of modern *Nautilus*, which has been interpreted by some students as indicating the size of the individual when it hatched from the egg.

In conclusion it should be mentioned that there seems to be no definite relationship between the development of complexity in the siphuncle and in the sutures of Late Paleozoic ammonoids. That is, some forms like the medlicottids with advanced sutures retain a primitive type of siphuncle throughout ontogenetic development. Also, in *Agathiceras*, in which the siphuncle is very primitive, the sutures are almost as complex as are those of the superficially similar adrianitids with highly modified siphuncular structures; and the septal necks of *Schistoceras* are comparable in their development to those of the perrinitids and cyclolobids, which are always regarded as some of the most advanced forms of Paleozoic ammonoids.

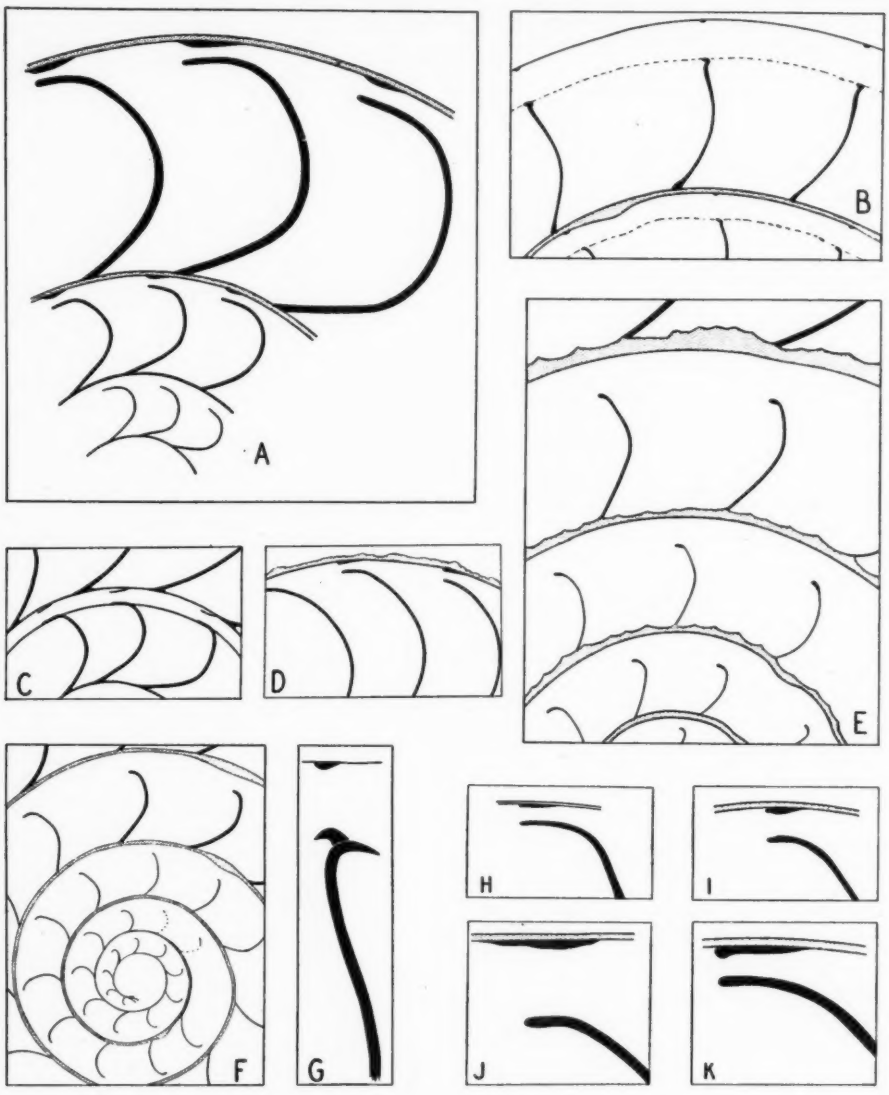

FIG. 3—Median dorsoventral sections of ammonoids.

A—Daraelites texanus Böse. Second, third, and fourth volutions; from the upper part of the Gaptank formations about 4½ miles S. 15° E. of Lenox, Texas (State Univ. Iowa, 1702), ×20.

B—Bisatoceras greenei Miller and Owen. From just above the Mulky coal member of the Cherokee shale in sec. 36, T. 43 N., R. 28 W., Henry County, Missouri (State Univ. Iowa, 1720), ×25.

C—Pronorites praepermicus Karpinsky. Early mature portion from the Artinskian beds near the Kossva River about 13 km. below Gubakha, west slope of Middle Urals, U. S. S. R. (State Univ. Iowa, 1686), ×20. Same specimen as text fig. 5F and pl. 1, fig. 3.

D—Propinacoceras affine Gemmellaro? Early mature portion from the Sosio beds (Calcare compatto) in the province of Palermo, Sicily (State Univ. Iowa, 1694), ×10.

(*Continued on opposite page*)

FAMILY BACTRITIDAE HYATT

The systematic position of the bactritids is uncertain, in that they are regarded by some paleontologists as nautiloids and by others as ammonoids. Typical Devonian, Mississippian, and Pennsylvanian forms are represented by text figure 2. In all of these the septa and the siphuncle are quite similar, suggesting that only one genus is represented but giving no indication as to whether it should be associated with the nautiloids or the ammonoids.

In the illustrated Devonian form, which came from the Antrim shale on the south side of Partridge Point, Michigan, where the conch is about 3.4 mm. high the siphuncle is about 0.2 mm. high, the camerae are about 1.2 mm. long, and about one-fifth of the length of the siphuncle is supported by the connecting rings. The Mississippian species came from the Caney shale of Oklahoma; where its conch is about 2.6 mm. high, its siphuncle is about 0.25 mm. high, the camerae are about 1.6 mm. long, and only about one-seventh of the length of the siphuncle is supported by the septal necks. The Pennsylvanian form came from the Cherokee shale of Henry County, Missouri; where its conch is about 3.7 mm. high, its siphuncle is about 0.2 mm. high, the camerae are about 3 mm. long, and only about one-eighth of the length of the siphuncle is supported by the septal necks.

FAMILY PRONORITIDAE FRECH[1]

Thin sections of typical representatives of three members of this family, *Pronorites*, *Prouddenites*, and *Uddenites*, are available for study. The septa and the siphuncle in all of these are quite similar and are relatively simple, and they resemble those of the more primitive medlicottids, e.g., *Artinskia* (text fig. 3H-K). That is, in median dorsoventral sections the septa are convex orad and are not sinuous; and the septal necks are merely adapical extensions of the septa, from which they do not differ in structure or composition.

In *Pronorites praepermicus* Karpinsky of the Artinskian of the Ural region, the protoconch is subcircular and its inner diameter measures about 0.58 mm. The adapical bulbous portion of the caecum is only slightly larger than the adoral portion of that structure, which lies between the prosepta (text fig. 5F). The prosiphon is visible in several of the available sections, in which it appears as a slightly curved fine line extending obliquely from the adapical end of the caecum to the inner wall of the protoconch. The prosepta are relatively far apart and are much thicker than the adapical septa; also their curvature is reversed from that of the septa, for they are slightly but distinctly concave adorally. The structures that correspond to the septal necks of the septa are short but very thick, and they extend both orad and apicad of the prosepta. The ventral portions of these necks are considerably larger than the dorsal portions. In the vicinity of the prosepta the dorsal wall of the conch is thick, but its thickness decreases gradually orad and more abruptly apicad, where a short flange is formed posterior to the adapical proseptum. In all of the several sections of this species being studied, there are either 10 or 11 septa in the first volution of the phragmacone, which is the same number that Böhmers found in *Pronorites timorensis* Haniel of the

[1] Regarded as a subfamily by Frech, 1901.

E—*Neoglyphioceras bellilineatum* Miller and Owen. From the same horizon and locality as *B* (State Univ. Iowa, 1714), ×40.

F, G—*Popanoceras annae* Ruzhencev. From the Artinskian beds near the Aktasty River in the Aktubinsk district, U. S. S. R. (State Univ. Iowa, 1777), ×25. *G*, a fully mature septal neck in the eighth volution of the conch.

H—*Uddenites oweni* Miller and Furnish. Mature septal neck from the upper part of the Gaptank formation about 5 miles northeast of Wolf Camp, Glass Mountains, Texas (State Univ. Iowa, 1693), ×10.

I—*Pronorites praepermicus* Karpinsky. Mature septal neck from the same horizon and locality as *C* (State Univ. Iowa, 1688), ×10.

J—*Artinskia falx* (Eichwald). Mature septal neck from the same horizon and locality as *C* and *I* (State Univ. Iowa, 1695), ×10.

K—*Prouddenites primus* Miller. Mature septal neck from the same horizon and locality as *A* (State Univ. Iowa, 1691), ×10.

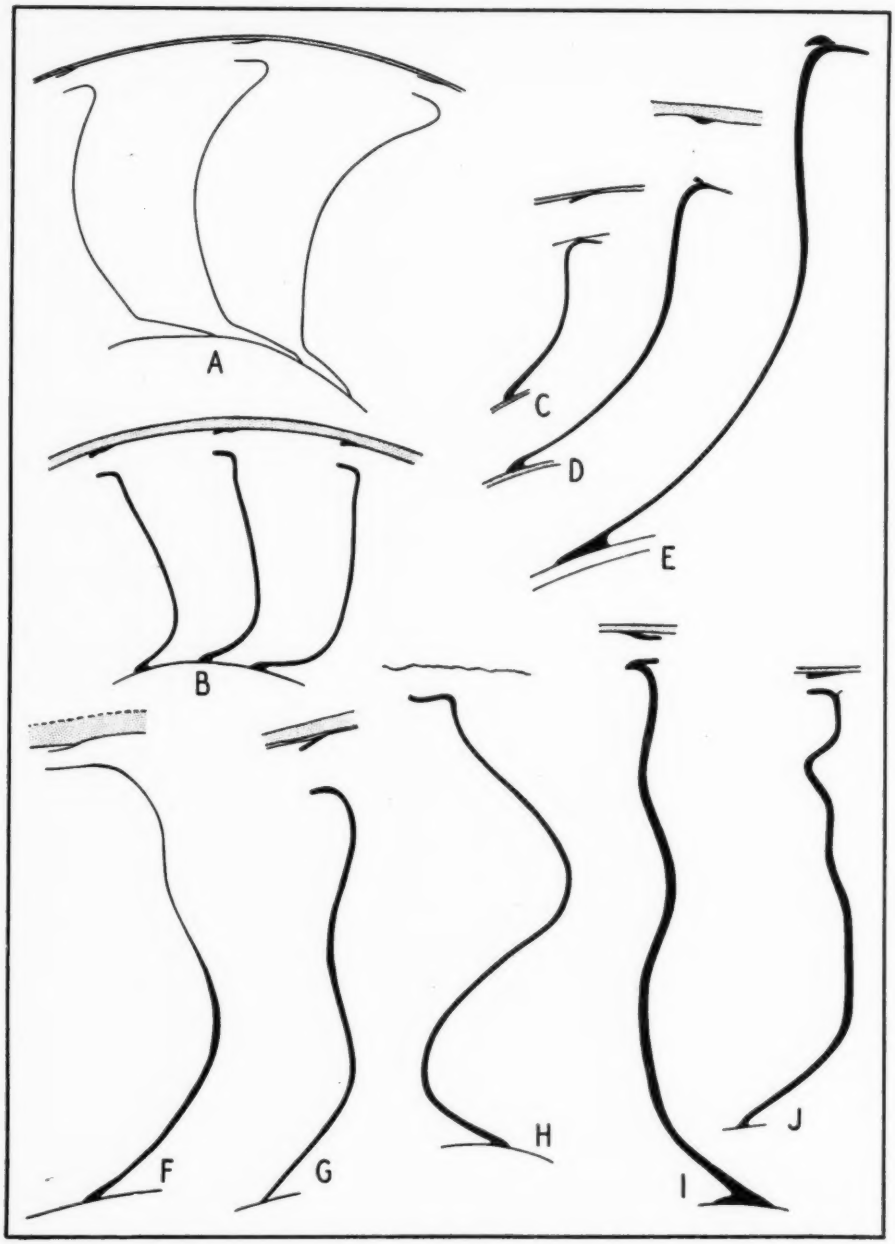

FIG. 4—Median dorsoventral sections of ammonoids

A—*Tornoceras uniangulare* (Conrad). From the Squaw Bay limestone on the south side of Partridge Point, south of Alpena, Michigan (State Univ. Iowa, 1707), ×10.
B—*Koenenites cooperi* Miller. From the same horizon and locality as *A* (State Univ. Iowa, 1708), ×10.

(*Continued on opposite page*)

Somohole beds of Timor—that species, however, has a distinctly smaller protoconch than does the form under consideration. The number of septa per volution increases slightly during ontogenetic development. In the second volution there are 13 or 14 septa, in the third the same number, and in the fourth (observed in only one specimen) 16. Throughout the entire length of the phragmacone the shape of the septa and the form of the septal necks do not vary appreciably (cf. text figs. 5F, 3C, and 3I). However, the height of the conch increases more rapidly than does that of the siphuncle—the disparity in this form is particularly marked as its whorls become strongly compressed during ontogenetic development. Near the midlength of the second volution the distance from the dorsum to the venter is about 6.5 times the height of the siphuncle; in the third volution it is about 9.5 times as great; and in the fourth about 15. The ratio of the dorsoventral measurement of the conch to the length of the camerae does not vary appreciably during ontogenetic development. In the second volution this ratio averages about 1.43, in the third about 1.27, and in the fourth about 1.57, but the spacing of the septa is somewhat irregular in all specimens. The amount of the siphuncle that is supported by the septal necks decreases relatively as the individual matures; in the second volution about one-half of the siphuncle is supported, in the third about two-fifths, and in the fourth only about one-fourth.

The general shape of the septa and the nature of the siphuncle in *Prouddenites* and *Uddenites* are essentially the same as in *Pronorites* (text figs. 3H-K). In *Prouddenites primus* Miller from the Gaptank formation near Lenox, Texas, there are 8 septa in the second volution of the phragmacone, 9 in the third, and 8 in the adapical half of the fourth. At full maturity in this species, where the distance between the dorsum and the venter measures about 10.3 mm. the siphuncle is about 0.28 mm. high and the camerae are about 3.5 mm. long. In this portion of the conch only about one-fifth of the siphuncle is supported by the septal necks. So little satisfactory material of *Uddenites* is available for study that precise data for that genus can not be obtained.

FAMILY MEDLICOTTIDAE KARPINSKY[2]

The collections being studied contain thin sections of well-preserved representatives of the three commonest genera of this family: *Propinacoceras*, *Artinskia*, and *Medlicottia*. The first two of these are very similar, and they resemble *Pronorites* closely; the third, however, differs in certain respects.

Böhmers (1936, p. 17 and pl. 2, fig. 1) has shown that in a typical representative of *Propinacoceras*, *P. simile* Haniel of the Basleo beds of Timor, the protoconch and the adapical portion of the phragmacone are almost precisely similar to those of *Pronorites praepermicus*, described above. In early mature specimens of *Propinacoceras affine* Gemmellaro? of the Sosio beds of Sicily, the septa are likewise convex adorally and are not sinuous, and the septal necks and connecting rings are essentially like those of *Pronorites praepermicus* (text figs. 3C, D).

[2] Regarded as a subfamily by Karpinsky, 1889.

C–E—Properrinites bakeri (Plummer and Scott). Septa of the fourth, fifth, and sixth volutions, from the Wolfcamp formation about 1 mile northeast of the crest of Dugout Mountain, Brewster County, Texas (State Univ. Iowa, 1790), ×25. Same specimen as pl. 5, fig. 3.

F—Protocanites lyoni (Meek and Worthen). From the Rockford limestone at Rockford, Indiana (State Univ. Iowa, 1703), ×4.

G—Cibolites sp. From the Capitan equivalent between Cerro Wencelao and Cerro El Indio, Valle de Las Delicias, Coahuila, Mexico (State Univ. Iowa, 1704), ×20.

H—Cibolites uddeni Plummer and Scott. From the Hegler limestone in the Pinyon Hills about 1.4 miles northeast of the Rim triangulation station, Culberson County, Texas (U. S. Geol. Survey collections), ×10.

I—Xenaspis skinneri Miller and Furnish. From the Pinery limestone about ½ mile northeast of the junction of Bell and Cherry canyons in a ravine on the north side of Cherry Canyon, Guadalupe Mountains, Texas (U. S. Geol. Survey collections), ×4.

J—Medlicottia burckhardti Böse. From the Word equivalent about 60 m. N. 35° E. of La Difunta, Valle de Las Delicias, Coahuila, Mexico (State Univ. Iowa, 1698), ×5.

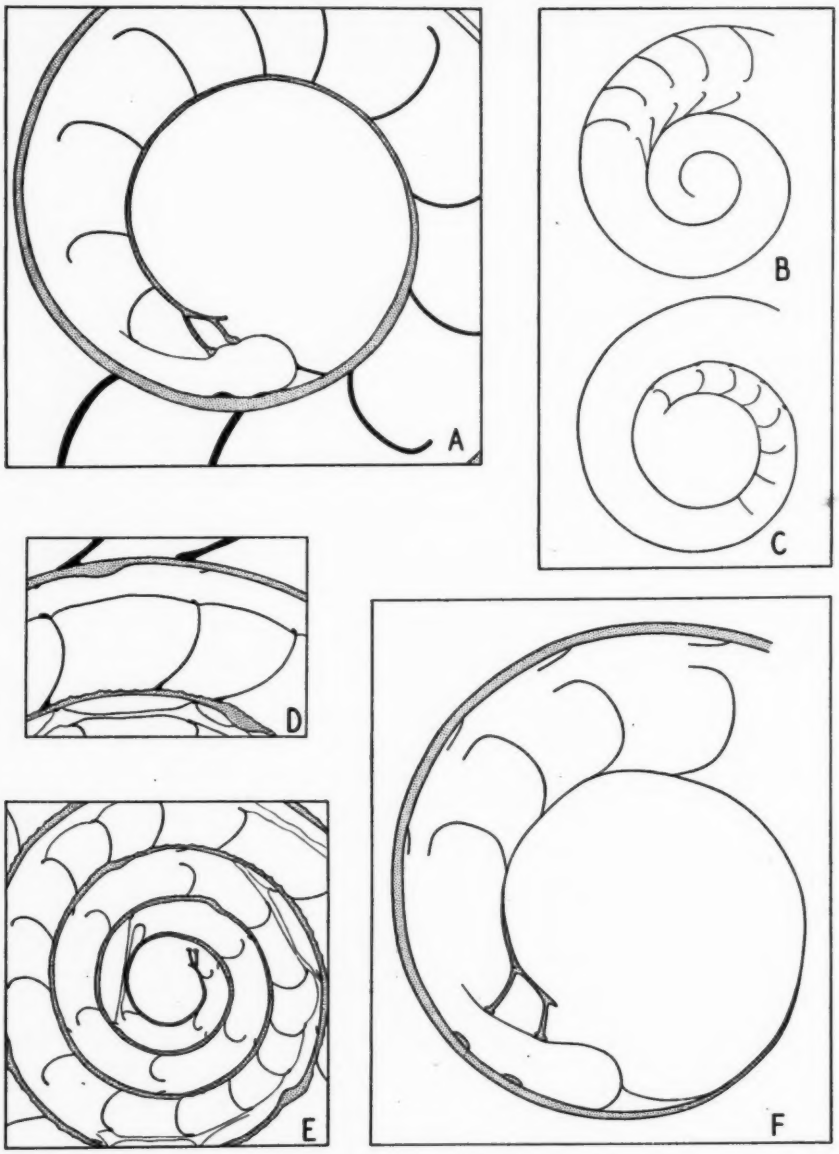

FIG. 5—Median dorsoventral sections of ammonoids

A—Goniolobоceras welleri Smith. From the Finis shale about 3 miles east of Jacksboro, Texas (State Univ. Iowa, 1743), ×50. Same specimen as pl. 1, fig. 4.
B—Imitoceras pygmaeum (Gemmellaro). From the Sosio beds (Calcare compatto) of the Province of Palermo, Sicily (State Univ. Iowa, 1747), ×10.
C—Imitoceras sp., From the Chouteau limestone on the County Farm about 1¼ miles north of Sedalia, Missouri (State Univ. Iowa, 1753), ×1½.
D, E—Eoasianites clinei (Miller and Owen). From the Seminole formation about ¾ mile south

(*Continued on opposite page*)

Two sections of *Artinskia falx* (Eichwald) from the Artinskian of the Ural Mountains are available for study, but unfortunately in both of them the inner volutions are not well preserved. However, an illustration of this or a rather closely related species from the Bitauni horizon in Timor was published by Böhmers (1936, p. 17, text fig. 7) and it shows that the protoconch is relatively small in comparison with that of *Pronorites* and *Propinacoceras*. Also, it should be noted that in *Pronorites* the two prosepta are almost parallel, in *Propinacoceras* they are considerably inclined to each other, and in *Artinskia* they are almost at right angles. The thin sections of the specimens from the Ural Mountains show that the shape of the septa and the structure of the siphuncle in the outer volutions are much as in *Pronorites praepermicus* (text figs. 3I, J).

The nature of the inner volutions of *Medlicottia* is not known, but several good sections of the outer whorls of *M. burckhardti* Böse from the zone of *Waagenoceras* in southwestern Coahuila have been prepared. These show that in at least the mature portion of the phragmacone the septa differ from those of *Pronorites*, *Propinacoceras*, and *Artinskia* in that they are sinuous, somewhat as in the Xenodiscidae (text figs. 6E, F and 4H-J). On the adoral side of the septa of this species, near their junctions with the septal necks, there is a small adoral projection which extends obliquely to the connecting ring (text figs. 6E, F), Another unique characteristic of this species is that during early maturity the connecting rings are continuous through the septal necks, but at late maturity they are discontinuous and extend only from the adapical ends of the septal necks into the adoral ends of the preceding necks (cf. text figs. 6E and 6F). Where the distance between the dorsum and the venter of the conch of *M. burckhardti* is about 12.15 mm., the height of the siphuncle measures about 0.39 mm., the average length of the camerae is about 3.7 mm., and approximately one-fourth of the length of the siphuncle is supported by the septal necks.

FAMILY DARAELITIDAE TSCHERNOW[3]

It has been demonstrated by Böhmers that in dorsoventral sections of *Daraelites submeeki* Haniel of the Bitauni beds of Timor, the protoconch, the prosepta, and the septa are essentially the same as in typical *Pronorites*. *Daraelites texanus* Böse of the Gaptank formation of west Texas also has a similar protoconch and similar septa, but the prosepta are not preserved in the only specimen available for study. The protoconch of this specimen is subcircular in shape, and its diameter measures about 0.43 mm. In the first volution of the phragmacone there are 10 septa, in the second 13, in the third 14, and in the fourth 16. These septa do not change in form throughout the length of the phragmacone, and also the nature of the siphuncle seems to be essentially constant (text fig. 3A). In the second volution of the phragmacone where the distance from the dorsum to the venter of the conch is about 0.38 mm. the height of the siphuncle is about 0.05 mm. and the septa are about 0.27 mm. apart; in the third volution where the dorsoventral measurement of the conch is about 0.7 mm. the siphuncle is about 0.055 mm. high and the camerae are about 0.5 mm. long; and corresponding measurements for the fourth volution are about 1.68 mm., 0.1 mm., and 1.4 mm., respectively. In the third volution about one-half of the length of the siphuncle is supported by the connecting rings, but in the fourth volution only about one-fourth of the length is thus supported.

FAMILY PARACELTITIDAE SPATH

Of the two genera now placed in this family, sections of only one, *Cibolites*, are available for study. In the type species of that genus, *C. uddeni* Plummer and Scott of

[3] Regarded as a subfamily by Tschernow, 1907.

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of Collinsville, Oklahoma (State Univ. Iowa, 1735), ×25. *E*, adapical three volutions, *D*, part of fourth volution of same specimen as pl. 2, fig. 2.

F—*Pronorites praepermicus* Karpinsky. From the Artinskian beds near the Kossva River about 13 km. below Gubakha, west slope of Middle Urals, U. S. S. R. (State Univ. Iowa, 1686), ×75. Same specimen as text fig. 3C and pl. 1, fig. 3.

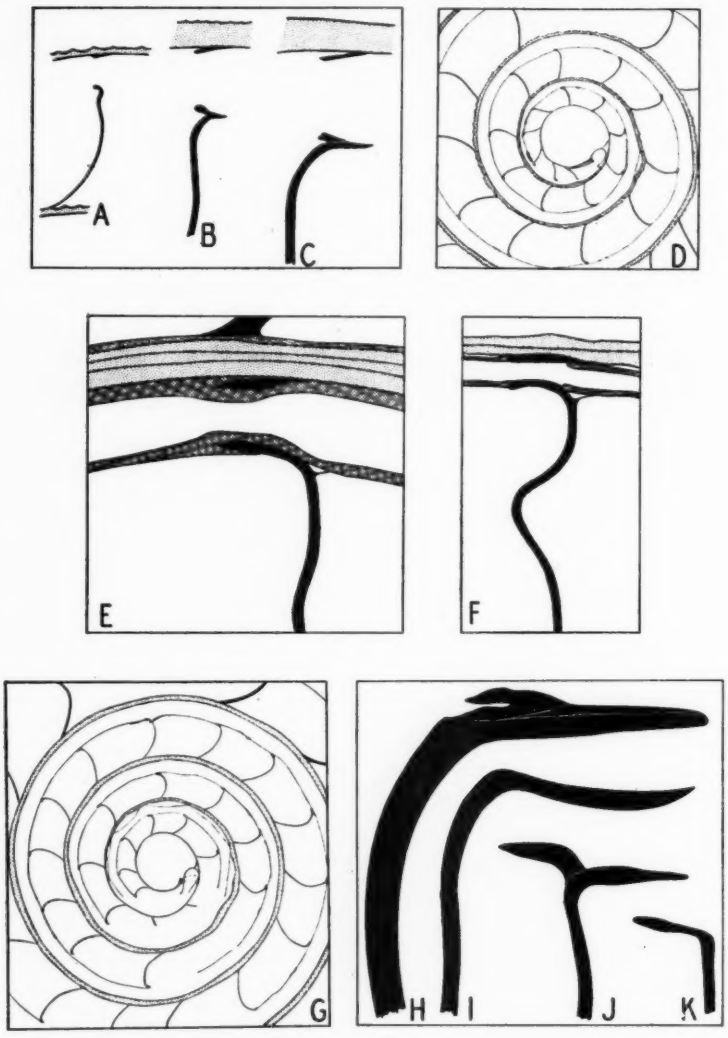


FIG. 6—Median dorsoventral sections of ammonoids.

A–C—Pseudogastrioceras suessi (Karpinsky). Septal necks near the midlength of the fifth, sixth, and seventh volutions, from the Artinskian beds near the Kossva River about 13 km. below Gubakha, west slope of Middle Urals, U. S. S. R. (State Univ. Iowa, 1739), ×25. Same specimen as pl. 2, fig. 5.

D—Pseudogastrioceras simulator (Girty). From the Phosphoria formation in Raymond Canyon of the Sublette Range, western Wyoming (State Univ. Iowa, 1740), ×25. Same specimen as pl. 3, fig. 1.

E, F—Medlicottia burckhardti Böse. Early and late mature septal necks of a specimen from the Word equivalent about 60 m. northeast of La Difunta, Valle de Las Delicias, Coahuila, Mexico (State Univ. Iowa, 1699). *E*, ×20; *F*, ×10.

G—Eoasianites welleri (Smith). From just above the Tebo coal member of the Cherokee shale in sec. 19, T. 24 N., R. 25 W., Henry County, Missouri (State Univ. Iowa, 1726), ×25. Same specimen as pl. 2 fig. 3.

H–K—Eoasianites welleri (Smith). Septal necks of the seventh, sixth, fifth, and fourth volutions, from just above the Mulky coal member of the Cherokee shale in sec. 15, T. 43. N., R. 28 W., Henry County, Missouri (State Univ. Iowa, 1723). *H*, ×50; *I–K*, ×65. Same specimen as pl. 2, fig. 4.

the Hegler limestone in west Texas, the septa in median dorsoventral sections are strongly sigmoidal, and the septal necks are simple retrosiphonate structures (text fig. 4H). In an unnamed species of *Cibolites* from the zone of *Timorites* in southwestern Coahuila, the septa are somewhat less strongly sigmoidal but the dorsal portion of them is recurved; and the septal necks are even more primitive than are those of *C. uddeni*. The septa of this latter species in median dorsoventral sections are very closely similar to those of *Protocanites lyoni* (Meek and Worthen) of the lower Mississippian Rockford limestone of Indiana (text figs. 4F, G). The simplicity of the septa in the Paraceltitidae is further emphasized by their similarity to those of such Devonian forms as *Tornoceras* and *Koenenites* (text figs. 4A, B), and it should be noted in this connection that median sections of the septa of the medlicottids resemble those of *Koenenites* (cf. text figs. 4J and 4B).

FAMILY XENODISCIDAE FRECH[4]

In general physiognomy the xenodiscids resemble the paraceltitids. Also the major flexures in the sutures of the two groups are quite similar, though the lobes of the xenodiscids are finely serrate, whereas those of the paraceltitids are not. The septa of the only available xenodiscid, *Xenaspis skinneri* Miller and Furnish of the Pinery limestone of west Texas, are much more strongly sinuous in median dorsoventral sections than are those of the paraceltitids (text figs. 4G-I). Furthermore, the septal necks of this species are far more advanced than are those of the paraceltitids, for they extend both apicad and orad of the septa. The main portion of the septal necks curves apicad from the septa, but there is a thin adoral extension which projects directly from the necks rather than from the septa. It therefore seems that whereas the paraceltitids most probably gave rise to the xenodiscids, they are much more primitive than their superficial similarity would seem to suggest.

Where the distance from the dorsum to the venter of the conch of *Xenaspis skinneri* is about 18.7 mm., the siphuncle is about 0.6 mm. high, the length of the camerae averages about 3.4 mm., and approximately one-sixth of the length of the siphuncle is supported by the septal necks.

[4] Regarded as a subfamily by Frech, 1902.

FAMILY CHEILOCERATIDAE FRECH

This family makes its appearance in the Upper Devonian, and with the exception of *Imitoceras* (and very closely related forms) is confined to that series. *Imitoceras*, however, has a phenomenally long range, and it continues through the Carboniferous and up into the Middle Permian Sosio beds of Sicily.

In the Mississippian, *Imitoceras* is widespread and abundant in North America, Europe, Asia, and Africa, but in the Western Hemisphere it appears to be absent from the upper portion of that system. However, all of the congeneric forms known from the Pennsylvanian came from North America, where they range in age from Cherokee to Wabaunsee and occur in Missouri, Kansas, Oklahoma, and Texas. Permian representatives of *Imitoceras* have been found only in the Sosio beds of Sicily, where they occur in association with *Waagenoceras* and many other forms generally regarded as about Middle Permian in age.

Peculiarly enough, all of the Pennsylvanian and Permian representatives of *Imitoceras* are very small, being 12 mm. or less in diameter. Furthermore, as shown by text figure 5B and by plate 3, figure 3, the siphuncle of these Late Paleozoic forms is not marginal in position, as is that of Mississippian specimens (text fig. 5C). None of the Cherokee specimens sectioned retains the internal structures, but in *I. grahamense* (Plummer and Scott) from the Wayland shale about 5 miles north of Jacksboro, Texas (State Univ. Iowa, 1793), where the conch is about 3.6 mm. in diameter, the dorsoventral measurement of the whorl is about 1.17 mm., and the siphuncle is about 0.17 mm. in diameter and is located about 0.35 mm. from the venter. Comparable measurements of *I. pygmaeum* (Gemmellaro) from the Permian Sosio beds of Sicily are about 4.2 mm., 1.38 mm., 0.216 mm., and 0.904 mm., respectively. Thus, in both the Pennsylvanian and the Permian forms the siphuncle is subcentral in position, but in the former it is closer to the venter than the dorsum, whereas in the latter the reverse

is the case. The fact that the siphuncle of these Late Paleozoic forms is not ventral and marginal in position suggests that they may not be as closely related to typical *Imitoceras* as their sutures and general physiognomy would seem to indicate. There may therefore be some justification for Plummer and Scott's genus *Neoaganides*, which was based on specimens from the upper Pennsylvanian of Texas, and the subcentral siphuncle even suggests a relationship to nautiloids, rather than to ammonoids. However, in all of the Late Paleozoic representatives of this family the septal necks are short and retrosiphonate, as are those of typical *Imitoceras*.

FAMILY GONIATITIDAE DE HAAN[5]

The Mississippian Caney shale of Oklahoma yields exceptionally well preserved specimens of a typical representative of *Goniatites*, *G. kentuckiensis* Miller. Longitudinal thin sections of these show that the protoconch is about 0.45 mm. in diameter. The whorls increase in height gradually and regularly. Near the midlength of the first volution the distance from the dorsum to the venter measures about 0.24 mm., and the corresponding measurement in the second volution is about 0.28 mm., in the third about 0.49 mm., in the fourth about 1.12 mm., in the fifth about 2.36 mm., and in the sixth about 3.7 mm. The siphuncle also expands orad gradually and regularly, and in at least the first six volutions of the conch its height is approximately one-seventh the dorsoventral measurement of the conch. Near the midlength of the second volution the height of the siphuncle measures about 0.04 mm., in the third volution about 0.14 mm., in the fourth about 0.24 mm., in the fifth about 0.33 mm., and in the sixth about 0.43 mm.

The number of septa per volution is fairly constant; in the second volution there are about 15 septa, in the third about 17, in the fourth about 14, in the fifth about 13, and in the sixth about 14. The length of the camerae increases regularly, and in the fourth, fifth, and sixth volutions (where accurate measurements were obtained) each camera is about twice as long as the corresponding one in the preceding volution. Near the midlength of the fourth volution the length of the camerae is about 0.65 mm., in the fifth volution about 1.37 mm., and in the sixth about 2.66 mm.

The septal necks are retrosiphonate throughout the phragmacone. Their relative length decreases during ontogenetic development, and it varies from about one-fourth that of the camerae in the fourth volution to about one-sixth in the sixth volution. Near the adapical end of each septal neck there is a slight but very distinct internal thickening which forms a bead there that serves to strengthen the necks and to provide a place of attachment for the connecting rings (text fig. 9M). In two of the three specimens sectioned (pl. 1, figs. 1, 2) the connecting rings are remarkably complete. They extend through the inside of the septal necks to the adoral portion of the internal bead in the necks and thus form an almost continuous tube.

FAMILY GASTRIOCERATIDAE WEDEKIND

This family is related to the Goniatitidae, and certain genera, like *Cravenoceras*, are more or less intermediate between typi-

[5] Familia *Goniatitea* de Haan, 1825.

EXPLANATION OF PLATE 1

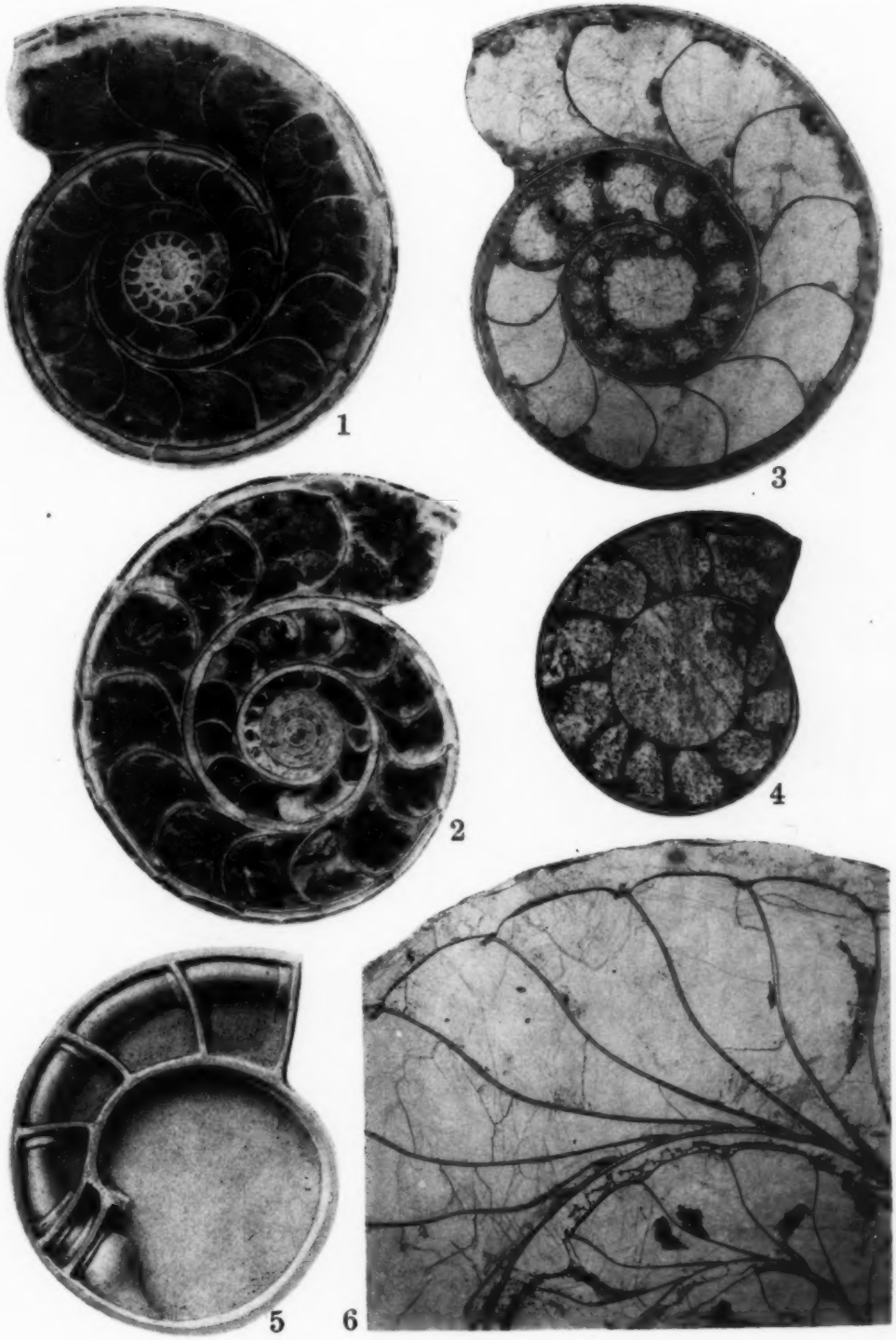
FIGS. *1, 2*—*Goniatites kentuckiensis* Miller. From the Caney shale near Ada, Oklahoma, ×6 (State Univ. Iowa, 1718 and 1717).

3—*Pronorites praepermicus* Karpinsky. From the lower Artinskian beds about 13 km. below Gubakha on the Kossva River, western slopes of Middle Urals, U. S. S. R., ×25 (State Univ. Iowa, 1686). Same specimen as text fig. 5F and 3C.

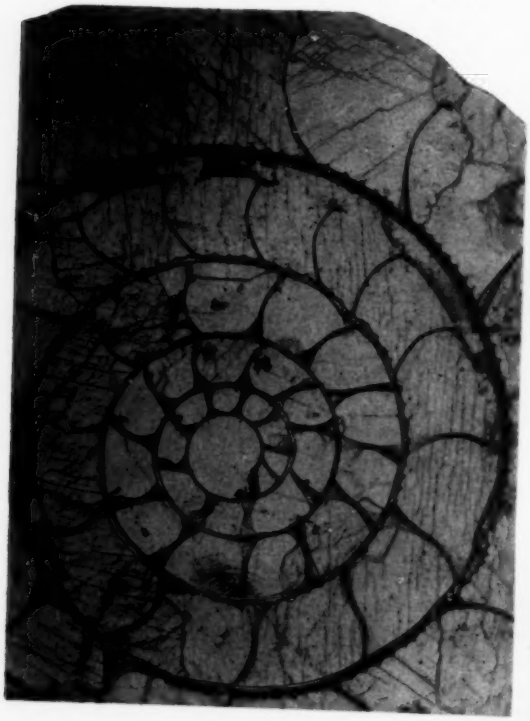
4—*Goniolobоceras welleri* Smith. From the Finis shale about 3 miles east of Jacksboro, Texas, ×25 (State Univ. Iowa, 1743). Same specimen as text fig. 5A.

5—Reconstruction of a pronoritid, showing protoconch, initial stages of siphuncle, early septa, etc., ×50.

6—*Eothalassoceras inexpectans* Miller and Owen. From the Coffeyville formation about ¾ mi. south of Seminole, Oklahoma, ×10 (State Univ. Iowa, 1759). Same specimen as text figs. 9A–D.



Miller and Unklesbay, Paleozoic Ammonoids



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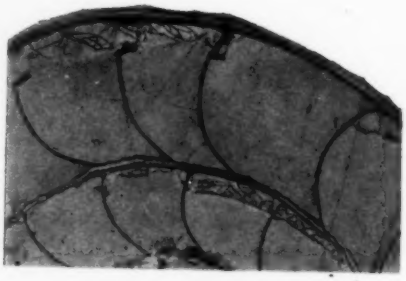

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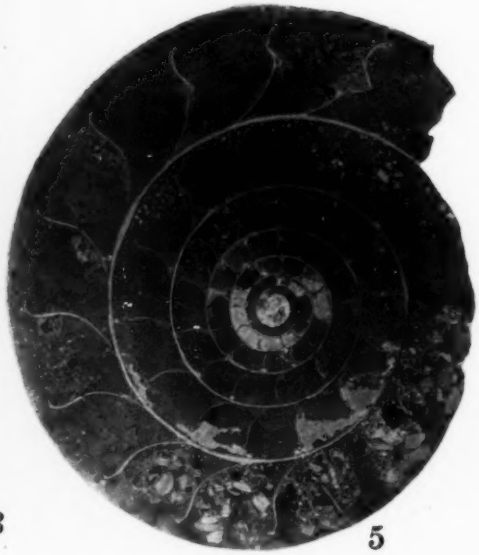

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Miller and Unklesbay, Paleozoic Ammonoids

cal representatives of the two. However, some members of the Gastrioceratidae, like *Schistoceras*, are quite distinct from the Goniatitidae.

Eosianites clinei (Miller and Owen), a typical gastrioceratid from the Pennsylvanian of Oklahoma, has a protoconch that in longitudinal thin sections is about 0.49 mm. in diameter. As shown by text fig. 5E, in this species the prosepta are distinctly thicker than the early septa, and the flange is very short. The angle between the flange and the adapical proseptum is rather small.

In two longitudinal median thin sections of *E. clinei* that are available for study, the heights of corresponding volutions of the conch vary somewhat. The dorsoventral measurements near the midlength of the first to the sixth volutions are about as follows: 0.14 mm. and 0.11 mm., 0.22 mm. and 0.22 mm., 0.33 mm. and 0.28 mm., 0.49 mm. and 0.42 mm., 0.81 mm. and 0.67 mm., and 1.26 mm. and 0.98 mm. Corresponding measurements of the height of the siphuncle are about: 0.056 mm. and 0.04 mm., 0.07 mm. and 0.042 mm., 0.084 mm. and 0.056 mm., 0.14 mm. and 0.084 mm., 0.21 mm. and 0.16 mm., and 0.27 mm. and 0.21 mm. At the adoral end of the first volution of the conch there is a prominent ventral constriction in all specimens studied, and a similar constriction is located about three-fourths of a volution orad of there. Comparable constrictions are present on the remaining portion of the phragmacone, where there are about three of them to the volution. The septa are somewhat irregularly spaced in different individuals and in different parts of the same individual. In the first volution of the specimen represented by text figure 5E and by plate 2, figure 2, there are 4 septa, in the second volution 6, in the third 14, in the fourth 11, in the fifth 14, and in the sixth 24. The average length of the camerae in each of these volutions is about: 0.41 mm., 0.49 mm., 0.39 mm., 0.66 mm., 1.12 mm., and 0.6 mm.

In the adapical five volutions of the conch of *E. clinei* the septal necks are all retrosiphonate and are very short; they are somewhat thicker than the septa. Within the adoral portion of the fifth volution and the adapical part of the sixth, the septal necks gradually change from retrosiphonate to prosiphonate.

Eoasianites jonesi (Miller and Owen), which also occurs in the Seminole formation near Collinsville, Oklahoma, is strikingly similar in median longitudinal thin section to *E. clinei*. That is, its protoconch is of about the same size, its prosepta and flange are of essentially the same magnitude and orientation, its septa are about equally spaced, and its siphuncle is of approximately the same relative size. Also, there is a constriction near the adoral end of the first volution of its conch and another about half of a volution orad of there.

Eoasianites welleri (Smith) of the Pennsylvanian Cherokee shale of Missouri has a relatively small protoconch, which in median longitudinal section is only about 0.4 mm. in diameter—in the sections available for study its diameter varies from 0.35 mm. to 0.42 mm. The specimen represented by plate 2, figure 3, and by text figure 6G shows a moderately well preserved caecum and a prosiphon. Within the thickness of the thin

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EXPLANATION OF PLATE 2

FIGS. *1*—*Neoglyphioceras bellilineatum* Miller and Owen. From just above the Mulky coal member of the Cherokee formation in sec. 36, T. 43 N., R. 28 W., Henry County, Missouri, ×25 (State Univ. Iowa, 1713).

2—*Eoasianites clinei* (Miller and Owen). From the Seminole formation about ¾ mi. south of Collinsville, Oklahoma, ×25 (State Univ. Iowa, 1735). Same specimen as text figs. 5D and 5E.

3—*Eoasianites welleri* (Smith). From just above the Tebo coal member of the Cherokee shale in sec. 19, T. 24 N., R. 25 W., Henry County, Missouri, ×25 (State Univ. Iowa, 1726). Same specimen as text figs. 6G.

4—*Eoasianites welleri* (Smith). From just above the Mulky coal member of the Cherokee formation in sec. 15, T. 43 N., R. 28 W., Henry County, Missouri, ×20 (State Univ. Iowa, 1723). Same specimen as text fig. 6H–K.

5—*Pseudogastrioceras suessi* (Karpinsky). From the lower Artinskian beds about 13 km. below Gubakha on the Kossva River, western slope of the Middle Urals, U. S. S. R., ×6 (State Univ. Iowa, 1739). Same specimen as text figs. 6A–C.

section, part of each proseptum is retained on one side of the caecum. The flange in this species is very short, and the angle between it and the adapical proseptum is fairly large.

The rate of adoral expansion of the conch of *Eoasianites welleri* varies considerably. In two well-preserved thin sections under consideration, near the midlengths of the first to the seventh volutions the dorsoventral measurements of the conch are as follows: 0.17 mm. and 0.16 mm., 0.224 mm. and 0.28 mm., 0.3 mm. and 0.42 mm., 0.42 mm. and 0.66 mm., 0.56 mm. and 1.05 mm., 0.77 mm. and 1.7 mm., and 1.16 mm. and 2.8 mm. As might be expected, the rate of adoral expansion of the siphuncle in these two sections is also quite different (though in the first two volutions there is little if any expansion). Near the midlength of the first seven volutions, the heights of the siphuncle in the two sections are as follows: 0.056 mm. and 0.056 mm., 0.056 mm. and 0.056 mm., 0.084 mm. and 0.07 mm., 0.112 mm. and 0.126 mm., 0.14 mm. and 0.21 mm., 0.22 mm. and 0.32 mm., and 0.23 mm. and 0.45 mm. In both of these sections the number of septa in corresponding volutions is essentially the same, though it increases progressively during ontogenetic development. The length of the camerae is less nearly regular, particularly in the fourth, fifth, and sixth volutions.

In the adapical three volutions of the conch of *E. welleri*, the septal necks are short, simple, and retrosiphonate (text fig. 6K)—however, they become somewhat longer during ontogenetic development. Near the midlength of the fourth volution they become somewhat modified, and for about one volution they are both retrosiphonate and prosiphonate (text fig. 6J). Near the midlength of the fifth volution they become entirely prosiphonate (text fig. 6I). In the adoral portion of the seventh volution auxiliary calcareous deposits are developed on the inside of the septal necks (text fig. 6H), presumably to strengthen these necks and to provide a place of attachment for the connecting rings. Extending apicad from the midportion of plate 2, figure 4, are the remains of what appears to have been a cylindrical network of somewhat calcified fibers in or around the siphuncle. Similar but less numerous fibers are also to be seen in the next larger volution of this specimen (the fourth volution), where they extend orad from the midlength of the figure.

Two median longitudinal thin sections of *Neoglyphioceras bellilineatum* Miller and Owen of the Cherokee of Missouri have protoconchs that are about 0.42 mm. and 0.45 mm. in diameter. In both of these the prosepta are thick, and the angle between the adoral proseptum and the short flange is relatively small (pl. 2, fig. 1). The rate of increase in height of at least the first volutions of the conch and the siphuncle is essentially the same in the two specimens. Near the midlength of the first six volutions of the conch the dorsoventral measurements average about as follows: 0.14 mm., 0.238 mm., 0.38 mm., 0.59 mm., 1.0 mm., and 1.89 mm. Corresponding measurements of the siphuncle in these six volutions are 0.042 mm., 0.042 mm., 0.056 mm., 0.098 mm., 0.19 mm., and 0.35 mm.

As in *Eoasianites clinei* and *E. jonesi*, there is a rather prominent ventral constriction near the adoral end of the first volution of the conch of *Neoglyphioceras bellilineatum*, another about three-fifths of a volution orad of there, and additional ones throughout the rest of the phragmacone at intervals of about one-third of a volution. Of particular note in this form are the thick test and the prominent growth lamellae (text fig. 3E). The spacing of the septa in both individuals under consideration is somewhat irregular, but there is approximately the same number of septa in corresponding volutions. In the first volution there are 8 or 9 septa, in the third 12, in the fourth 13 or 14, in the fifth 15 or 18, and in the sixth 19.

The septal necks in the adapical five volutions of *Neoglyphioceras bellilineatum* are short and are retrosiphonate. They are merely thickened adapical projections of the septa. In the adapical portion of the sixth volution the septal necks become both retrosiphonate and prosiphonate, but this condition continues for only four or five septa, after which the necks become prosiphonate. About one-seventh of the siphuncle is supported by the septal necks in the first volution, but this fraction decreases to about one-fifteenth in the second volution

and to only about one-twentieth in the third, only to increase again in the fourth to about one-fifteenth, in the fifth to about one-twelfth, and in the sixth to about one-fifth.

Two median longitudinal thin sections through the protoconch of *Bisatoceras greenei* Miller and Owen of the Cherokee of Missouri were prepared. In all available particulars they are essentially alike. The protoconch is small, and its diameter measures only about 0.28 mm. Traces of a caecum and two prosepta are discernible in one of the sections, but the preservation leaves much to be desired. The dorsoventral measurements of the conch near the midlength of the first six volutions are as follows: 0.126 mm., 0.21 mm., 0.35 mm., 0.546 mm., 0.7 mm., and 1.176 mm. Corresponding measurements of the siphuncle in the fourth, fifth, and sixth volutions are 0.112 mm., 0.14 mm., and 0.238 mm., respectively. The number of septa per volution decreases from 8 in the first to 6 in the second, but then it increases to 10 in the third and fourth, to 12 in the fifth, to 13 in the sixth, and to 21 in the seventh. The adapical two and one-half volutions are devoid of ventral constrictions, but in the rest of the phragmacone there are about three of them to the volution. The septal necks of this form differ from those of the other gastrioceratids available for study (cf. text figs. 3B and 3E), and they are exceedingly short and remain retrosiphonate throughout the phragmacone of the largest specimen sectioned, which attains a diameter of about 10 mm. In the fourth volution of the conch only about one sixty-fifth of the siphuncle is supported by the septal necks, in the fifth about one thirty-fifth, and in the sixth about one-fifth.

Very little detailed information is available in regard to the internal structures of *Anthracoceras*, but one rather poor section of *A. missouriense* Miller and Owen of the Cherokee of Missouri is available. In this section the protoconch is about 0.28 mm. in diameter. The adapical two volutions of the phragmacone are very poorly preserved, but near the midlength of the third the dorsoventral measurement of the conch is about 0.51 mm., and corresponding measurements of the next three volutions are about 0.81 mm., 1.6 mm., and 3.87 mm., respectively. Near the midlength of the fifth and sixth volutions the height of the siphuncle measures about 0.21 mm., and about 0.43. The length of the camerae increases progressively orad, but, peculiarly, there are 12 septa in the third, the fourth, and the fifth volutions. As shown by text figure 9G, the septal necks in the sixth volution of the conch are prosiphonate and are of moderate length, being about one-fifth as long as the camerae. Due to the inadequacy of the available material, uncertainty exists as to the precise nature of the siphuncle, but there appear to be modified auxiliary deposits in association with the septal necks, presumably to strengthen them and to provide places of attachment for the connecting rings. Somewhat similar deposits occur in *Goniloboceras* and *Neodimorphoceras* (text figs. 9E, F).

The protoconch of *Goniloboceras welleri* Smith of the Pennsylvanian Finis shale of Texas is unusually large, and in longitudinal thin section its diameter measures about 0.8 mm. In one of the available sections both the prosiphon and the caecum are well preserved, and the latter is about 0.172 mm. high (text fig. 5A and pl. 1, fig. 4). The two prosepta are thick and are relatively far apart. The angle between the adapical proseptum and the moderately long flange is fairly large. Near the midlength of the first five volutions of the conch, the dorsoventral measurements of the whorls are about as follows: 0.387 mm., 0.731 mm., 1.38 mm., 3.65 mm., and 9.16 mm. The spacing of the septa is somewhat irregular, but the camerae become progressively longer throughout ontogenetic development. In the first volution of the well-preserved section under consideration there are 11 septa, in the second 15, in the third 20, in the fourth 22, and in the fifth 28 (estimated). The siphuncle is relatively small, and near the midlength of the fifth volution its height measures about 0.387 mm. In the two adapical volutions of the conch the septal necks are simple adapical projections of the septa. Their nature in the third and fourth volutions can unfortunately not be ascertained from the available material, but in the fifth and sixth volutions they extend both orad and apicad of the septa, though the adapical projection and the inner portion of the adoral one ap-

pear to be auxiliary deposits (text fig. 9F).

Pseudogastrioceras simulator (Girty) of the Permian Phosphoria formation of western Wyoming has a protoconch that in longitudinal section is about 0.42 mm. in diameter. The caecum is about 0.08 mm. in height, and

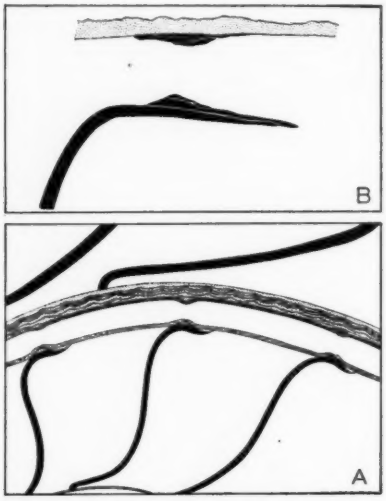

FIG. 7—*Schistoceras missouriense* (Miller and Faber). Median dorsoventral sections of (*A*), early mature and (*B*), late mature portions of the phragmacone. From the Finis shale about 3 miles east of Jacksboro, Texas (State Univ. Iowa, 3119 and 1744), both ×10 *A* represents the same specimen as pl. 3, fig. 4.

it is preceded by a typical prosiphon. As shown by plate 3, figure 1, and text figure 6D, apparently the adoral proseptum is poorly developed and no flange is present. In a well-preserved but unfigured thin section, near the midlength of the whorls the dorsoventral measurements of the first seven volutions of the conch are about as follows: 0.14 mm., 0.25 mm., 0.38 mm., 0.64 mm., 1.05 mm., 1.82 mm., and 3.78 mm.—the last is in the living chamber. Corresponding measurements of the figured specimen are essentially identical. At the adoral end of the first volution there is a rather prominent ventral expansion of the conch in both of the sections being studied. Throughout the length of the phragmacone, the height of the siphuncle is approximately one-fourth the dorsoventral measurement of the conch. The septal necks are retrosiphonate in the first four volutions, but in the fifth and the sixth volutions they gradually change to prosiphonate, which condition then continues throughout the remainder of the phragmacone. Somewhat as in *Neoglyphioceras bellilineatum*, discussed above, the test is relatively thick in this species and it bears prominent transverse growth lines.

A moderately well preserved longitudinal section of *Pseudogastrioceras suessi* (Karpinsky) from the lower Artinskian beds of the Urals has a protoconch that is about 0.46 mm. in diameter. The rate of adoral expansion of the conch of this form is similar to that of *P. simulator* in the first four volutions but is smaller in the next ones. Near the midlength of the first eight volutions, the dorsoventral measurements of the conch are about as follows: 0.15 mm., 0.22 mm., 0.31 mm., 0.49 mm., 0.71 mm., 1.08 mm., 1.9 mm., and 3.35 mm. There are 11 septa in both the third and the fourth volutions, 13 in each of the next two, 14 in the seventh, and 15 in the eighth. The length of the camerae is variable in the first six volutions but becomes regular in the seventh and eighth volutions. The height of the siphuncle measures about 0.08 mm. near the midlength of the fourth volution, about 0.16 mm. in the corresponding portion of the fifth volution, about 0.21 mm. in the sixth, 0.24 mm. in the seventh, and 0.49 mm. in the eighth. As shown by plate 2, figure 5, throughout the first four volutions the septal necks are simple and are retrosiphonate. In the fifth an adoral salient is developed just dorsad of the septal necks (text fig. 6A). This salient gradually becomes a distinct adoral projection so that the septal necks are both retrosiphonate and prosiphonate (text fig. 6B). Eventually the retrosiphonate portions of the septal necks seem to become auxiliary (text fig. 6C).

None of the several available sections of *Schistoceras missouriense* (Miller and Faber) from the Finis shale and the Wolfcamp formation of Texas shows the nature of the protoconch or the inner portions of the phragmacone. The conch expands orad fairly rapidly and near the midlength of the fourth? volution the dorsoventral measurement of the phragmacone is about 6 mm. This volution contains 18 septa. The siphuncle is relatively small, and where the dorso-

ventral measurement of the conch is about 1.5 mm., the height of the siphuncle is about 0.17 mm. The septal necks become prosiphonate very early in this form; whereas the nature of the innermost volutions can not be ascertained from the available material, it can be seen that orad of the third volution the septal necks are entirely prosiphonate. As shown by text figure 7A and plate 3, figure 4, during early maturity

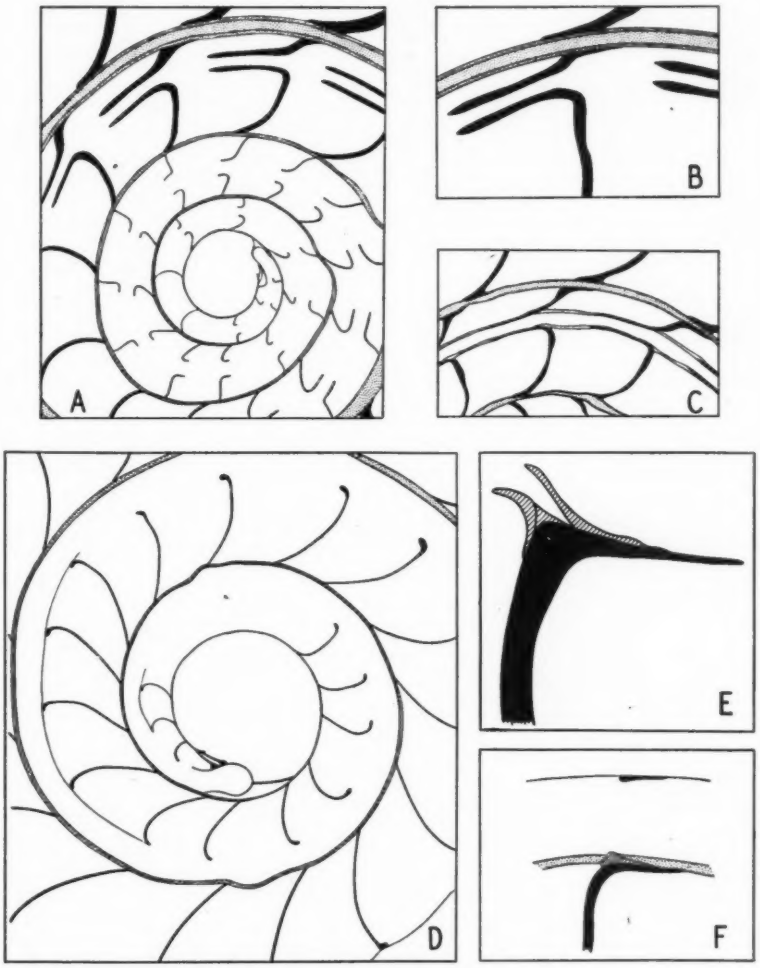

FIG. 8—Median dorsoventral sections.

A, B—Agathiceras applini Plummer and Scott. From the Admiral formation about 5 miles south-southwest of Coleman, Texas (State Univ. Iowa, 1766), ×25. *A*, the adapical three volutions of the specimen illustrated by pl. 4, fig. 4; *B* part of the fourth volution of the same specimen.

C—Agathiceras uralicum Karpinsky. From the Artinskian beds on the right bank of the Sim River near the Sim works in the Middle Urals, U. S. S. R. (State Univ. Iowa, 1767), ×25. Same specimen as pl. 4, fig. 5.

D, E—Adrianites dunbari Miller and Furnish. From the Capitan equivalent near La Difunta, Valle de Las Delicias, Coahuila, Mexico (State Univ. Iowa, 1764). *D* (×25) and *E* (×50) represent the same specimen as pl. 4, figs. 2, 3. *E* represents a fully mature septal neck in the sixth volution of the conch.

F—Waagenoceras dieneri girtyi Miller and Furnish. Septal neck in early mature portion, from a slightly lower horizon at the same general locality as *D, E* (State Univ. Iowa, 1783), ×25.

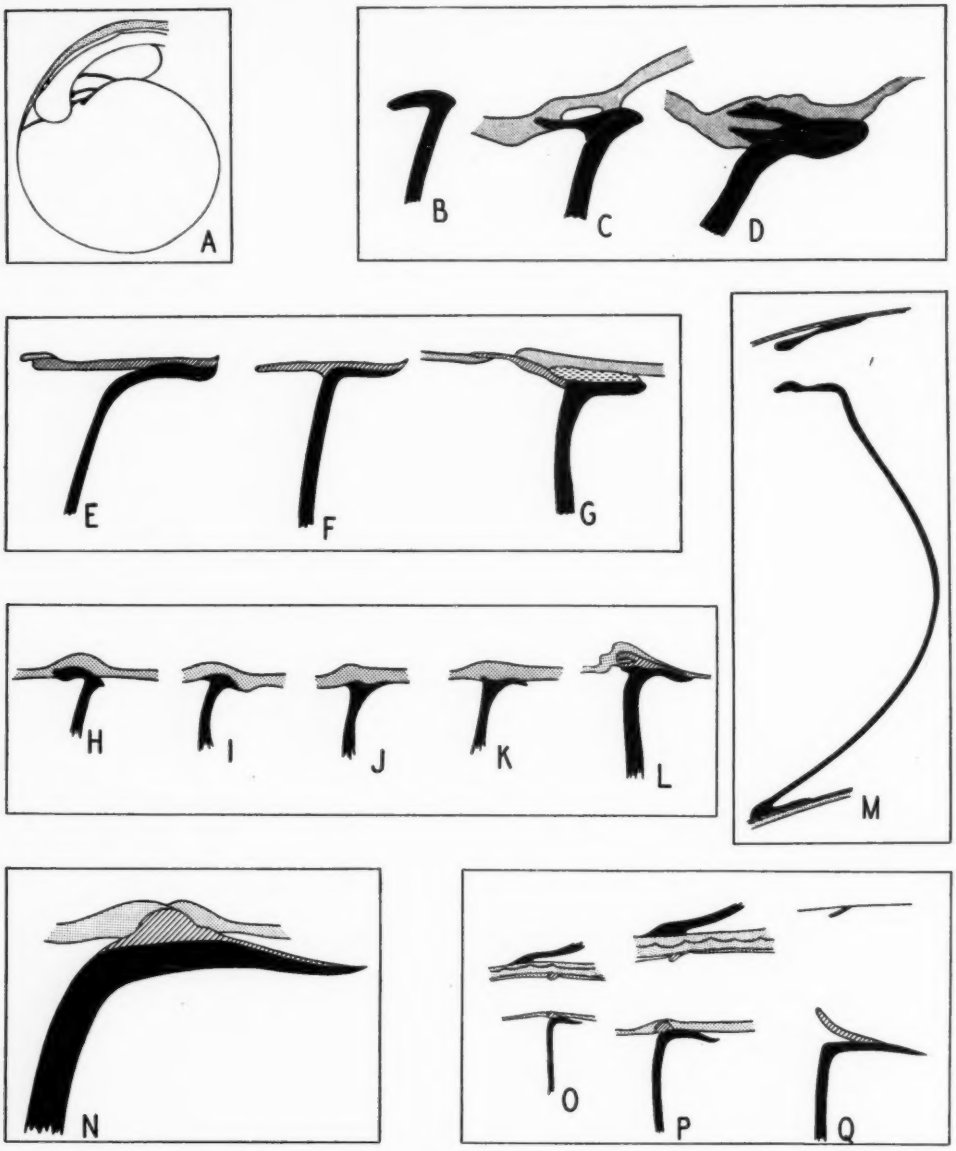

FIG. 9—Median dorsoventral sections of ammonoids.

A–D—Eothalassoceras inexpectans (Miller and Owen). From the Seminole formation about ¾ mile south of Collinsville, Oklahoma, all based on a single specimen (State Univ. Iowa, 1759), and all ×75. *A*, the protoconch and the extreme adapical portion of the phragmacone; *B–D*, septal necks near the adapical end of the fourth volution of the conch, near the mid-length of the same volution, and near the adapical end of the fifth volution. Same specimen as pl. 1, fig. 6.

E—Neodimorphoceras texanum (Smith). Mature septal neck from the Jacksboro limestone near Jacksboro, Texas (State Univ. Iowa, 1757), ×11.

(*Continued on opposite page*)

auxiliary deposits are formed inside the septal necks and the connecting rings are attached to them. It should perhaps be mentioned that the connecting rings are continuous through the septal necks. During late maturity the auxiliary deposits inside the septal necks become more complex (text fig. 7B).

FAMILY DIMORPHOCERATIDAE HYATT

The two genera *Dimorphoceras* and *Neodimorphoceras* seem to constitute a group distinct enough to be regarded as an independent family. Typical *Dimorphoceras* appears in the Viséan and continues through the Pennsylvanian as *Neodimorphoceras*. There is more or less complete gradation between these two genera, but typical *Neodimorphoceras* can be said to have evolved about the middle of the Pennsylvanian period. At about the same time, the thalassoceratids arose from this stock, and they continued into the Permian whereas the dimorphoceratids disappeared near the close of the Pennsylvanian.

In *Dimorphoceras politum* (Shumard) of the Cherokee of Missouri (pl. 3, fig. 5) the protoconch is fairly large (0.45 mm. in diameter), and the whorls are rapidly expanded orad. The dorsoventral measurement of the conch is about 0.168 mm. near the midlength of the first volution, 0.294 mm. in the corresponding part of the second volution, 0.756 mm. in the third volution, and 2.31 mm. in the fourth. There is a ventral constriction near the adoral end of the first volution of the conch, another near the adoral end of the second volution, five in the adapical half of the third, but none orad of there. The prosepta are short, are only slightly thicker than the first septa, and are relatively far apart; and the angle between the adapical proseptum and the short flange is fairly small. In the first three volutions of the phragmacone, the septa are relatively far apart (there being seven in both the second and the third volutions), but their spacing is somewhat irregular. In the fourth volution of one of the specimens sectioned, the septa become relatively close together (there being 17 in this volution), and in the adoral volution of a fully mature specimen they are very closely spaced. The siphuncle, which is relatively small, does not expand as rapidly as does the conch. Near the midlength of the second volution, its height measures about 0.098 mm., and corresponding measurements in the third and fourth volutions are about 0.14 mm. and 0.238 mm., respectively. In at least the first four volutions of the conch, the septal necks are simple and are retrosiphonate, but at full maturity they are complex and extend both apicad and orad of the septa.

As shown by text figure 9E, *Neodimorphoceras texanum* (Smith) of the Jacksboro limestone of Texas has complex septal necks at maturity. These necks extend both apicad and orad of the septa, but the adapical projections seem to be auxiliary calcareous deposits which are attached to the inside of the adorally projecting necks.

FAMILY THALASSOCERATIDAE HYATT

No sections of typical *Thalassoceras* of the Permian are available for study, but the

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F—Goniloboceras welleri Smith. Mature septal neck from the Finis shale about 3 miles east of Jacksboro, Texas (State Univ. Iowa, 1741), ×25.

G—Anthracoceras missouriense Miller and Owen. Mature septal neck from 10–15 feet below the Jordan coal member of the Cherokee shale in sec. 17, T. 41 N., R. 25 W., Henry County, Missouri (State Univ. Iowa, 1721), ×45.

H–L—Stacheoceras toumanskyae Miller and Furnish. From the Capitan equivalent east of La Difunta, Valle de Las Delicias, Coahuila, Mexico. *H*, A neck in the adoral portion of the fourth volution of the conch; *I–K*, necks in the adapical part of the fifth volutions (State Univ. Iowa, 1776), all ×70. *L*, A fully mature septal neck (State Univ. Iowa, 1775), ×25.

M—Goniatites kentuckiensis Miller. A mature septum from the Caney shale near Ada, Oklahoma (State Univ. Iowa, 1716), ×10.

N–Q—Perrinites hilli (Smith). Septal necks. *N*, A fully mature portion of a specimen at a diameter of about 140 mm., from the Leonard equivalent near Puerto de Sardinas in the Valle de Las Delicias, Coahuila, Mexico (State Univ. Iowa, 1787), ×5—the same specimen as pl. 5, fig. 5. *O–Q*, Necks in about the second, third, and fourth volutions of a specimen from the Leonard formation approximately 1 mile west of the southern end of Iron Mountain, Brewster County, Texas (State Univ. Iowa, 1785), ×25. Same specimen as pl. 5. fig. 4.

collections under consideration contain several sections of *Eothalassoceras inexpectans* (Miller and Owen) of the Pennsylvanian Seminole formation of Oklahoma. One of these sections (text fig. 9A) elucidates the internal structures of the conch very well. The protoconch is of about average size, and its diameter measures about 0.36 mm. The caecum is about 0.056 mm. high, and it is preceded by a rather short prosiphon. The adapical proseptum is much shorter than the adoral, and the angle between it and the short flange is rather small. Both the prosepta and the first septum are thick, but the second septum is not. In three well-preserved sections there are 5 septa in the first volution, 8 to 10 in the second, 8 in the third, and 8 in the fourth. The rate of adoral expansion of the conch is moderately rapid. Near the midlength of the first four volutions of the conch of one specimen the dorsoventral measurements are about 0.112 mm., 0.224 mm., 0.504 mm., and 1.4 mm., respectively; and in the fifth and sixth volutions of another specimen corresponding measurements are about 2.8 mm. and 4.34 mm., respectively. There is a ventral constriction near the adoral end of the adapical volution of the conch. The siphuncle is relatively small and does not expand orad as rapidly as does the conch. Near the midlength of the second, third, fourth, and fifth volutions of the specimen mentioned above, the height of the siphuncle measures about 0.042 mm., 0.112 mm., 0.21 mm., and 0.42 mm., respectively. The septal necks of the first three volutions of the same specimen are retrosiphonate (text fig. 9B), but near the midlength of the fourth volution they become thicker and project both orad and apicad of the septa. In the adapical portion of the fifth volution (and orad of there) the septal necks are prosiphonate but they retain adapical extensions (text fig. 9D and pl. 1, fig. 6).

FAMILY AGATHICERATIDAE ARTHABER

The nature of the internal structures in the genus *Agathiceras* is known through the work of Schindewolf and Böhmers, both of whom studied specimens from the Permian of Timor. The sections of American and Russian specimens that are now available confirm the results obtained by these two European authors and differ from the forms they studied only in detail.

The protoconch of *Agathiceras* is large and, as shown by text figure 8A and plate 4, figure 4, that of *A. applini* Plummer and Scott of the Permian Admiral formation of Texas measures about 0.49 mm. in diameter. The caecum in this species is about 0.098 mm. high and is preceded by a fairly long prosiphon. The prosepta, which are parallel, are thin and form a small angle with the short flange. The rate of adoral expansion of the conch is not very great. Near the adapical end of the first, second, third, fourth, and fifth volutions, the dorsoventral measurements of the conch are about 0.098 mm., 0.21 mm., 0.35 mm., 0.658 mm., and 1.26 mm., respectively. The number of septa per volution increases progressively, and there are 8 in the first volution, 11 in the second, 12 in the third, 13 in the fourth, and 14 in the fifth. At the extreme adapical end of the protoconch, the siphuncle is central in position, It gradually migrates ventrad

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EXPLANATION OF PLATE 3

FIG. *1*—*Pseudogastrioceras simulator* (Girty). From the phosphatic shale member of the Phosphoria formation on the south side of Raymond Canyon, Sublette Range, western Wyoming [near Raymond, Idaho], ×25 (State Univ. Iowa, 1740). Same specimen as text fig. 6D.

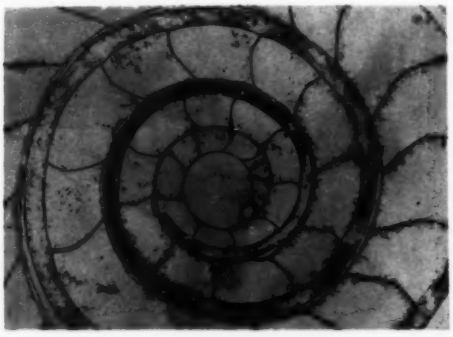
2—*Properrinites bakeri* (Plummer and Scott), from the Wolfcamp formation about 10 mi. northeast of the crest of Dugout Mountain, Brewster County, Texas, ×25 (State Univ. Iowa, 1789). See also pl. 5, fig. 3.

3—*Imitoceras pygmaeum* (Gemmellaro). From the Sosio beds (Calcare compatto) in the province of Palermo, Sicily, ×40 (State Univ. Iowa, 1748).

4—*Schistoceras missouriense* (Miller and Faber). From the Finis shale about 3 mi. east of Jacksboro, Texas, ×10 (State Univ. Iowa, 3119). Same specimen as text fig. 7A.

5—*Dimorphoceras politum* (Shumard). From just above the Mulky coal member of the Cherokee formation in sec. 36, T. 43 N., R. 28 W., Henry County, Missouri, ×10 (State Univ. Iowa, 1755).

6—*Shumardites cuyleri* Plummer and Scott. From the Finis shale about 4¾ mi. northwest of Jacksboro, Texas, ×3 (State Univ. Iowa, 1791).



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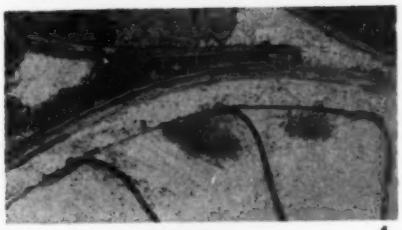

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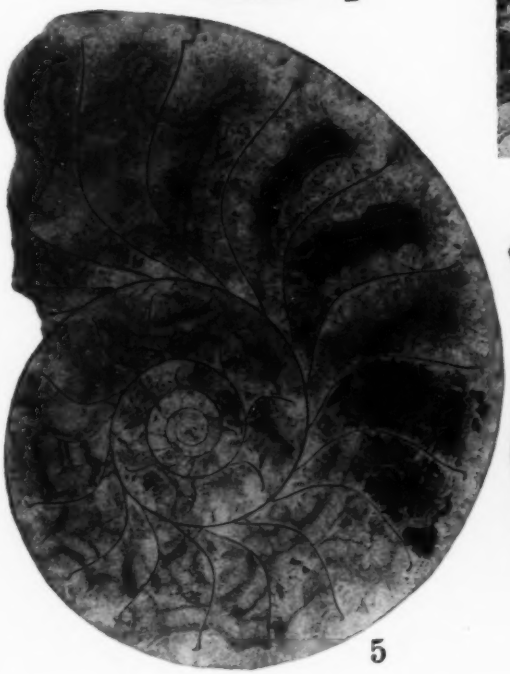

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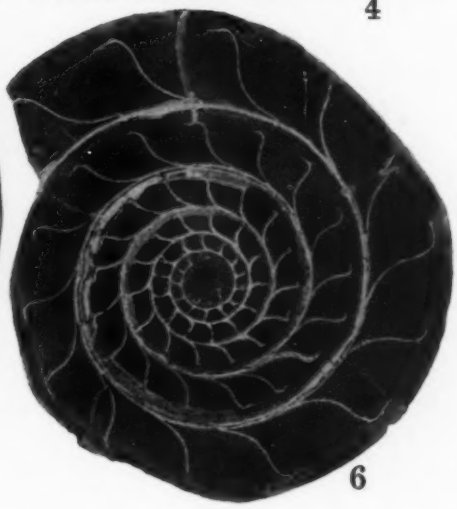

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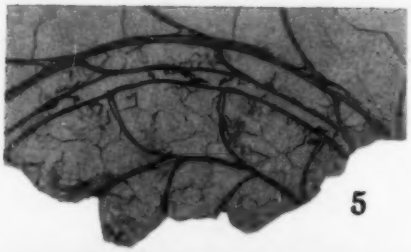
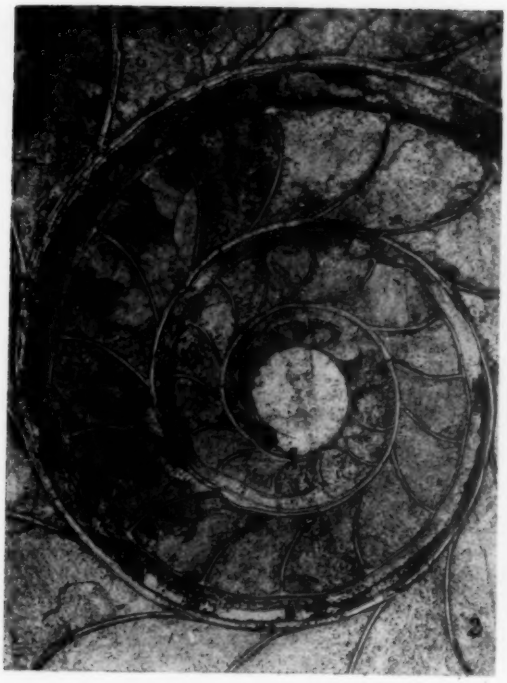
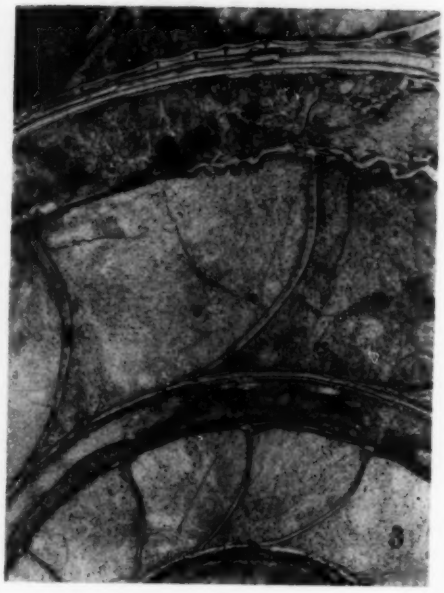
Miller and Unklesbay, Paleozoic Ammonoids







Miller and Unklesbay, Paleozoic Ammonoids

and becomes marginal near the adoral end of the third volution. The septal necks are retrosiphonate throughout ontogenetic development, and their relative length, as well as their actual length, increases progressively. In the adapical volution of the conch the necks are about one-fifth as long as the camerae, in the third volution they are about one-third as long as the camerae, and in the fourth volution they are about three-fourths as long as the camerae, after which they continue to be about five-sixths as long as the camerae. The siphuncle does not appear to have remained precisely in the dorsoventral plane throughout ontogenetic development, as shown by text figure 8A and by plate 4, figure 4. It should be mentioned that near the adoral end of the first volution, there is a distinct ventral expansion of the conch.

In *Agathiceras uralicum* Karpinsky of the Artinskian on the right bank of the Sim River near the Sim Works in the Middle Urals (text fig. 8C and pl. 4, fig. 5) the septal necks are similarly long and the siphuncle does not become marginal in position until a fairly late stage in development is attained. The connecting rings extend from the outside of the adapical ends of the septal necks into the infundibular adoral ends of the adjacent necks.

FAMILY ADRIANITIDAE SCHINDEWOLF

The internal structures of typical representatives of the genus *Adrianites* from the Permian of Timor have been studied by Schindewolf and Böhmers. Nevertheless, it seems desirable to publish detailed measurements of an American form, even though it does not differ greatly from the congeneric Timor species.

Several sections of *Adrianites dunbari* Miller and Furnish from the Upper Permian (Captain equivalent) of Coahuila, Mexico, have been prepared. These show that the protoconch in this species is slightly larger than in the Timor forms that have been studied, and that its diameter measures about 0.476 mm. The caecum, which is preceded by a fairly long prosiphon, is almost 0.1 mm. high. The prosepta are closely spaced and are not greatly thickened. The adapical one forms a small angle with the flange, which is very short (text fig. 8D). As in the Timor representatives of *Adrianites*, the number of septa per volution is rather large, and in the sections under consideration the first volution contains 12–14 septa, the second, 14 or 15, the third 14, the fourth 13, and the fifth 12. The conch expands adorally at a moderate rate, and the dorsoventral measurement in the specimen represented by plate 4, figure 1, is about 0.21 mm. near the midlength of the first volution, 0.29 mm. in the second volution, 0.518 mm. in the third, 1.4 mm. in the fourth, 2.66 mm. in the fifth, and 5.18 mm. in the sixth. As in *Agathiceras applini* and *Pseudogastrioceras simulator*, there is a fairly prominent ventral expansion of the conch near the adoral end of the first volution. As shown near the upper margin of plate 4, figure 3, there are small vertical structures in the walls of this species, which are reminiscent of the punctae in brachiopods. The surface of the test is distinctly elevated immediately above each of these vertical structures, suggesting that they may have been developed in connection with the growth lines. Their distribution and their prominence are somewhat irregular, but traces of them can be discerned throughout much of the conch.

The siphuncle of *Adrianites dunbari* is fairly large and is ventral in position throughout ontogenetic development. Near the midlength of the first to the sixth volutions of

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EXPLANATION OF PLATE 4

FIGS. *1–3*—*Adrianites dunbari* Miller and Furnish. From the Capitan equivalent (zone of *Timorites*) along the strike between Cerro Wencelao and Cerro El Indio in the Valle de Las Delicias of Coahuila, Mexico, ×25 (State Univ. Iowa, 1765 [fig. *1*] and 1764 [figs. *2*, *3*]). *2*, *3*, Same specimen as text figs. 8D and 8E.

4—*Agathiceras applini* Plummer and Scott. From the Admiral formation about 5 mi. south-southwest of Coleman, Texas, ×25 (State Univ. Iowa, 1766). Same specimen as text figs. 8A and 8B.

5—*Agathiceras uralicum* Karpinsky. From the Artinskian beds on the right bank of the Sim River at the Sim Works in the Middle Urals, U. S. S. R., ×25 (State Univ. Iowa, 1767). Same specimen as text fig. 8C.

the conch, the height of the siphuncle measures about 0.042 mm., 0.056 mm., 0.182 mm.. 0.35 mm., 0.7 mm., and 0.98 mm., respectively. In the first two volutions the septal necks are simple and retrosiphonate. Near the adoral end of the second volution they change abruptly (within two or three septa) to a prosiphonate condition. The necks are fairly short but they become relatively longer during later growth stages—in the second volution they are only about one-fourteenth as long as the camerae, whereas in the fifth volution they are approximately one-fourth as long as the camerae. In the fourth volution, complex auxiliary deposits are developed inside the septal necks (text fig. 8E). These deposits extend apicad of the necks and provide places of attachment for the connecting rings, which appear to form a continuous tube.

FAMILY POPANOCERATIDAE HYATT

As understood by us, this family includes only three valid genera: *Peritrochia*, *Stacheoceras*, and *Popanoceras*. None of the several sections of *Peritrochia* prepared is very satisfactory. Nevertheless, it is clear that the septal necks in this genus become prosiphonate during very early ontogenetic development, and that auxiliary deposits are developed inside the septal necks at about the same time that they become prosiphonate. At maturity the septal necks are about one-third as long as the camerae and in general physiognomy they seem to resemble those of *Schistoceras* more than they do those of *Stacheoceras* and *Popanoceras*. The siphuncle is small and its height is only about one-eighth to one-tenth the dorsoventral measurement of the conch.

The protoconch of *Stacheoceras toumanskyae* Miller and Furnish of the Capitan horizon in the Valle de Las Delicias of Coahuila, Mexico, is about 0.266 mm. in diameter, which is slightly less than that of the congeneric forms from Timor that Böhmers studied. The preservation of the Mexican specimens is such that the nature of the prosepta can not be ascertained,but presumably they are like those of *S. tridens* of Timor. In that species the prosepta are not parallel, they are considerably thickened, and they extend apicad from the short flange, with which the adapical proseptum forms a small angle. In *S. toumanskyae* the length of the camerae is irregular in the early volutions of the conch, but it becomes more nearly stabilized in the later volutions. There are 11 septa in the first volution, 11 in the second, 13 in the third, 16 in the fourth, 18 in the fifth, and 20 (estimated) in the sixth. The conch expands orad at a moderate rate, and near the midlength of the first to the seventh volutions, the dorsoventral measurements of the conch are about 0.14 mm., 0.21 mm., 0.36 mm., 0.60 mm., 1.05 mm., 1.89 mm., and 2.94 mm., respectively. The siphuncle is moderate in size and its height near the midlength of the third to the seventh volutions measures about 0.112 mm., 0.196 mm., 0.28 mm., 0.35 mm., and 0.63 mm., respectively. In the first four volutions the septal necks are fairly simple and retrosiphonate (text fig. 9H), but in the adapical portion of the fifth volution they change rapidly and become prosiphonate (text fig. 9I–K). At full maturity they are prosiphonate and carry complex auxiliary deposits to which the connecting rings are attached (text fig. 9L).

In *Popanoceras annae* Ruzhencev of the Artinskian beds near the Aktasty River in the Aktubinsk district, U. S. S. R., the protoconch is about 0.308 mm. in diameter. The two prosepta are not greatly thickened, though the adapical one is somewhat thicker than the adoral one. The adapical proseptum, which makes a small angle with the short flange, is convex apicad, whereas the adoral one is slightly convex orad (text fig. 3F). The conch increases in size at a moderate rate, and near the midlength of the first eight volutions the dorsoventral measurements of the whorls are about 0.112 mm., 0.21 mm., 0.308 mm., 0.49 mm., 0.728 mm., 1.176 mm., 1.988 mm., and 3.43 mm., respectively. Near the adoral end of the first volution of the conch, there is an external ventral thickening of the test, and throughout the rest of the phragmacone ventral constrictions are present at irregular intervals. The spacing of the septa is fairly regular, though the number of septa per volution increases progressively throughout early ontogenetic development; in the first volution there are 9 septa, in the second 10, in the third 11, in the fourth 12, in the fifth

16, in the sixth 19 and in the seventh 19. The septal necks are invariably rather short. In the first six volutions they are simple and retrosiphonate, but near the adapical end of the seventh volution they become prosiphonate as well as retrosiphonate. Even in the adoral portions of the phragmacone the septal necks remain both prosiphonate and retrosiphonate (text fig. 3G). The siphuncle is small and does not expand very rapidly; near the midlength of the first volution its height is about 0.028 mm., and corresponding dimensions in the next seven volutions are about 0.042 mm., 0.056 mm., 0.098 mm., 0.14 mm., 0.196 mm., 0.28 mm., and 0.42 mm., respectively. Böhmers shows the auxiliary deposits on the septal necks of *Popanoceras hanieli* Smith from the Permian of Timor as being forked, but in the Russian specimens under consideration they are undivided.

FAMILY SHUMARDITIDAE PLUMMER AND SCOTT

A single section of a typical representative of this family *Shumardites cuyleri* Plummer and Scott of the Finis shale of Texas is available for study (pl. 3, fig. 6). The extreme adapical portion of this specimen is not well preserved. However, it can be seen that the conch expands orad rather gradually (in at least a dorsoventral direction), the spacing of the septa is fairly regular, and the siphuncle is moderate in size. During very early ontogenetic development the septal necks are retrosiphonate, but they soon become prosiphonate. At about the stage where the necks become prosiphonate, they develop internal auxiliary deposits to which the connecting rings are attached. At full maturity the septal necks resemble those of *Schistoceras* very closely (cf. pl. 3, figs. 4 and 6).

FAMILY PERRINITIDAE MILLER AND FURNISH

Very satisfactory thin sections of two of the three genera that compose this family are available for study, and the internal structures for the other genus (*Hyattoceras*) have been investigated by Böhmers. In *Properrinites bakeri* (Plummer and Scott) from the Wolfcamp formation about 1 mile northeast of Dugout Mountain in the Glass Mountain region of Brewster County, Texas (pl. 3, fig. 2; and pl. 5, fig. 3) the protoconch is fairly large, its diameter measuring about 0.63 mm., and the caecum is also large, being about 0.168 mm. high. The prosepta are very short and are only slightly thickened. The adapical proseptum forms a small angle with the exceedingly short flange. The conch is moderately expanded orad, and near the midlength of the first six volutions the dorsoventral measurements of the whorls are about 0.21 mm., 0.322 mm., 0.602 mm., 1.19 mm., 2.03 mm., and 2.64 mm. Near the adoral end of the first volution of the conch there is a distinct ventral constriction. The spacing of the septa is fairly regular, and in the first volution of the conch there are 9 septa, in the second 13, and in the third 14. The siphuncle is moderate in size, and near the midlength of the first six volutions of the conch its height measures about 0.07 mm., 0.07 mm., 0.14 mm., 0.28 mm., 0.35 mm., and 0.62 mm., respectively. The septal necks are retrosiphonate in the first two and one-half volutions of the conch, after which they become prosiphonate and develop auxiliary deposits, which extend somewhat apicad of the septa (text figs. 4C–E, and pl. 5, fig. 3). The septal necks are of only moderate length throughout ontogenetic development.

The internal structures of *Perrinites hilli* (Smith) of the Leonard formation of west Texas and equivalent beds in Coahuila do not differ greatly from those of *Properrinites*. The conch in this species is rather rapidly expanded orad. The siphuncle is moderately small, and its height is only about one-seventh of the dorsoventral measurement of the whorl (pl. 5, fig. 4). The nature of the septal necks during the earliest ontogenetic stages is not known, but at least where the dorsoventral measurement of the conch is more than 1.36 mm. the necks are prosiphonate and carry small internal auxiliary deposits. As shown by text figures 9P and 9Q, during ontogenetic development the auxiliary deposits become relatively long and thin and change in shape from a simple ring to a more or less infundibuliform structure. In a very large specimen from the Leonard horizon in southwestern Coahuila, the septal necks at a diameter of about 140 mm. bear well-developed internal auxiliary

deposits, to which the connecting rings are attached (text fig. 9N). The connecting rings are continuous through the septal necks, but they are greatly thinned as they cross the auxiliary portion of the necks. It seems from the work of Böhmers that the internal structures of *Hyattoceras* do not differ greatly from those of *Properrinites* and *Perrinites*.

FAMILY CYCLOLOBIDAE ZITTEL

Waagenoceras, a typical member of this family, is represented in the available collections by several sections belonging in two species. In *W. guadalupense* Girty of the South Wells limestone near South Wells, Culberson County, Texas, the protoconch is about 0.49 mm. in diameter. The prosepta are somewhat thickened, and the adapical one, which is shorter than the adoral one, forms a small angle with the long thin flange (pl. 5, fig. 1). The conch is expanded orad rather gradually, and near the midlength of the first seven volutions the dorsoventral measurements of the whorls are about 0.14 mm., 0.224 mm., 0.42 mm., 0.658 mm., 1.07 mm., 1.61 mm., and 2.38 mm., respectively. Near the adoral end of the first volution there is a distinct ventral constriction, and corresponding constrictions occur at irregular intervals throughout the remainder of the phragmacone. The septa are irregularly spaced, and, peculiarly, there are 9 septa in each of the first two volutions of the figured specimen and 16 in each of the following four volutions. In the fifth, sixth, and seventh volutions, the length of the camerae is approximately equal to the dorsoventral measurement of the conch. The siphuncle is large, and throughout much of the phragmacone its height is equal to approximately one-third of the dorsoventral measurement of the conch. In the adapical two and one-half volutions of the conch the septal necks are retrosiphonate and are rather simple. Near the midlength of the third volution the necks rapidly become prosiphonate and at early maturity they are slender attenuate prosiphonate extensions of the septa. They bear internal auxiliary deposits, to which the connecting rings are attached.

Waagenoceras dieneri girtyi Miller and Furnish of the Word equivalent northeast of La Difunta in the Valle de Las Delicias, Coahuila, Mexico, has a protoconch which is slightly smaller than that of *W. quadalupense* and measures about 0.448 mm. in diameter (pl. 5, fig. 2). The conch of this form is expanded orad rather gradually, and near the midlength of the first ten volutions the dorsoventral measurements of the whorls are about 0.168 mm., 0.168 mm., 0.308 mm., 0.49 mm., 0.7 mm., 1.02 mm., 1.75 mm., 2.73 mm., 3.99 mm., and 6.44 mm., respectively. The siphuncle is moderate in size, and near the midlength of the third volution its height measures about 0.07 mm.; corresponding measurements of the fourth to the tenth volutions are about 0.14 mm., 0.21 mm., 0.28 mm., 0.49 mm., 0.56 mm., 0.7 mm., and 0.98 mm., respectively. The septal necks become prosiphonate in the adapical portion of the fifth volution. They are quite similar to those of *W. guadalupense* in that they are long and slender and support about one-third to one-fourth the length of the siphuncle. As shown by text figure 8F, the necks bear internal auxiliary deposits, to which the connecting

EXPLANATION OF PLATE 5

FIG. 1—*Waagenoceras quadalupense* Girty. From the South Wells limestone opposite Long Point north of D Ranch, South Wells, in the Guadalupe Mountain region of Culberson County, Texas, ×10 (State Univ. Iowa, 1782).

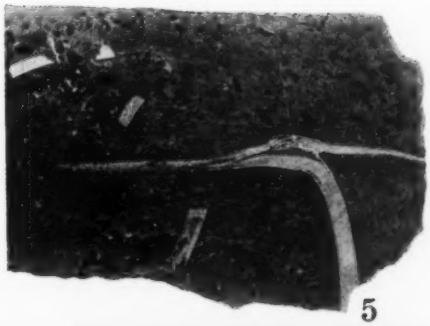
2—*Waagenoceras dieneri girtyi* Miller and Furnish. From the Word equivalent about 60 mi. N. 35° E. of La Difunta in the Valle de Las Delicias of Coahuila, Mexico, ×3 (State Univ. Iowa, 1784).

3—*Properrinites bakeri* (Plummer and Scott). From the Wolfcamp formation about 1 mi. northeast of the crest of Dugout Mountain, Brewster County, Texas, ×8 (State Univ. Iowa, 1790). Same specimen as text figs. 4C–E. See also pl. 3, fig. 2.

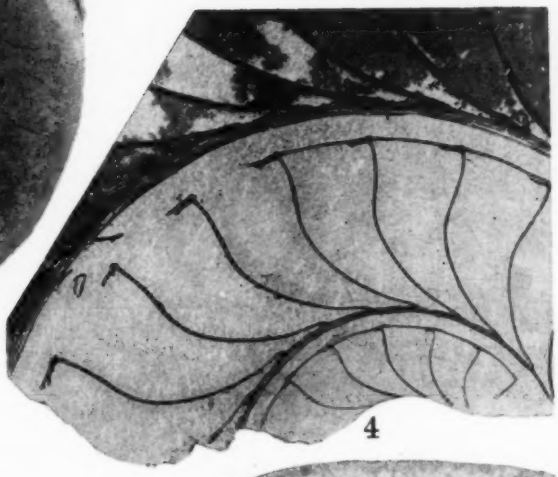
4—*Perrinites hilli* (Smith). From the Leonard formation about 1 mi. west of the southern end of Iron Mountain, Brewster County, Texas, ×8 (State Univ. Iowa, 1785). Same specimen as text figs. 9O–Q.

5—*Perrinites hilli* (Smith). From the Leonard equivalent about 1 km. S. 80° E. of Puerto de Sardinas in the Valle de Las Delicias of Coahuila, Mexico, ×4 (State Univ. Iowa, 1787). Same specimen as text fig. 9N.

1

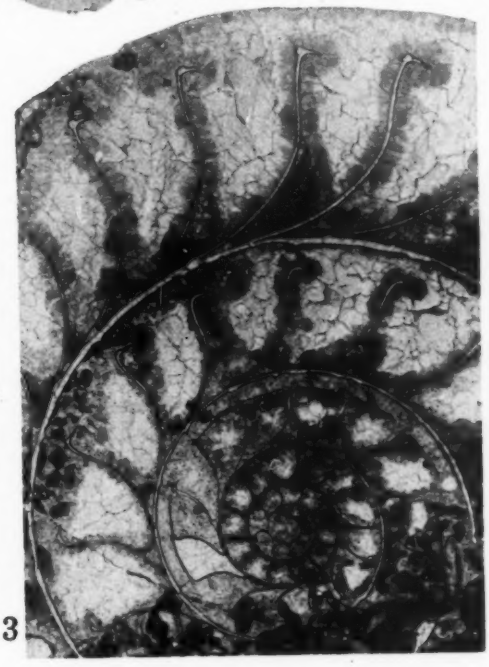


5



4

2



3

Miller and Unklesbay, Paleozoic Ammonoids

rings are attached. These rings, however, do not appear to be continuous within the septal necks. It should probably be mentioned in this connection that Böhmers' illustrations show the septal necks of *Timorites striatus* Haniel and *T. persulcatus* (Rothpletz), both of the Permian of Timor, to be quite similar to those of the American representatives of *Waagenoceras* under consideration.

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THE DISCOVERY OF FOSSIL VERTEBRATES IN NORTH AMERICA

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ABSTRACT—Aside from casual finds without scientific sequel, the discovery of fossil vertebrates in North America may be credited to Charles Le Moyne, second Baron de Longueuil, a (French) Canadian, whose party found mastodon remains along the Ohio River in 1739. The circumstances are detailed and some previous misapprehensions corrected. Longueuil's locality may have been Big Bone Lick, but quite possibly was not. If not, no one name can be attached to the discovery of that most famous of pioneer fossil localities. Croghan visited the lick in 1765, and in 1766 he obtained a collection from there which he sent to London, but, even apart from Longueuil, the locality was well known to white settlers and naturalists before 1765 and collections had been made there before Croghan's.

INTRODUCTION

MUCH HAS BEEN written, in widely scattered notes and comments, about the first discoveries of fossils in North America, but this literature is full of contradictions and misapprehensions and is usually lacking in corroborative detail. In preparing a more general history of American vertebrate paleontology up to 1842 for the American Philosophical Society, I have recently had occasion to investigate the earliest discoveries. Evidence previously adduced by various historians but not all known to any one of them was gathered and compared, while important evidence not hitherto considered in this connection was found. It has thus become possible to clear up much of the confusion and to offer an account that is likely to be definitive as far as it goes, although as usual some new problems arise that can only be settled by future research, if at all. Even though material already easily available to paleontologists is merely mentioned or summarized in briefest fashion, such an attempt at definitive statement requires more details regarding certain incidents in the period 1736–1766 than can properly be given in a paper on the long span 1519–1842. These necessary details are therefore separately presented in the present study.

So many people have become interested in this historical research and have contributed materially to it that it has become almost a communal project. Thanks are due, first of all, to Mr. Regis Roy of Ottawa, who devoted much time and patient skill to searching for and abstracting pertinent information. Mr. Lawrence J. Burpee, Ottawa, placed me in touch with Mr. Roy and also assisted greatly in other ways. Mr. A. J. H. Richardson, Public Archives, Ottawa, sent me a copy of the important letter, Wright to Bartram, here reproduced. Through G. Lanctot, Deputy Minister, the Public Archives of Canada supplied a photograph of the crucial, hitherto unpublished Mandeville-de Lery map of the Ohio. My original enquiry after informants and information from Canada, so richly successful, was forwarded by Dr. L. S. Russell of Toronto. The librarians of the New York Public Library, of the American Museum of Natural History, and of the American Philosophical Society (particularly Mrs. Gertrude Hess) were uniformly helpful. Dr. W. R. Jillson of Frankfort, Kentucky, leading historian of Big Bone Lick, supplied some data personally as well as through his publications. My wife, Dr. Anne Roe, did part of the bibliographic research. Assistance from others relating chiefly to the period subsequent to 1766 but also with some bearing on the present work will be acknowledged in the more general historical study from which this special paper has arisen.

FIRST GLIMPSES

There are different definitions of "discovery," and the discussion may be meaningless without further specification. From the point of view of scientific history, merely seeing a fossil bone or picking it up in idle curiosity is hardly discovery. It is

proposed to speak of discovery in much the same sense that Columbus may correctly be said to have discovered America. For present purposes, the scientific discovery was that which initiated continuous consciousness and record of the occurrence of fossil animals in America and had the first scientific studies as its sequel. Some finds were made before this discovery, just as some Europeans (and perhaps also Asiatics and Polynesians) visited America before Columbus.

Finds of fossil shark teeth in pre-Columbian sites of the Southeastern States and of fossil invertebrates over a wider area (Ball, 1941) prove that even relatively savage tribes did pick up fossils on occasion. These were doubtless medicine, like many stones of odd shape or color, and no knowledge of their organic origin is indicated. Kindle (1935) devoted a special study to Indian discoveries of fossil vertebrates, but only three instances are circumstantially given and these are all relatively late, long after white men were thoroughly familar with similar fossils.[1] Kindle and apparently all other paleontologists[2] have hitherto overlooked a true find by Indians that gives them unquestionable priority and that carries the history (or prehistory) of vertebrate paleontology in America back to the astonishingly early date of 1519. In that year Cortez and his army were in Tlascala (Mexico) where the natives showed them great bones believed to be those of human giants. A thigh bone was sent to the king in Spain. (See the account of Diaz del Castillo.) This surely refers to a fossil proboscidean, but the reaction of the king, who had asked for gold and was given a bone, is lost to posterity, as is the subsequent fate of the gigantic femur.

In 1636 Samuel Maverick reported the finding of buried whale bones on the James River in Virginia, but there is no way of knowing whether these belonged to an extinct animal. In 1686 the famous pioneer naturalist John Banister is said to have had in his possession large bones and teeth from the interior of Virginia, which may well have been true fossils but, again, are unidentifiable and had no scientific consequences. (On both incidents see Goode, 1901.) Around 1705 and 1706 several bones and teeth, probably of mastodons, were found at localities along the Hudson River. Governor Dudley of Massachusetts informed Cotton Mather of these finds (see Dudley's letter in Warren, 1855), and in 1712 Mather sent a curious communication touching on them to London, where his letter was summarized and published by the Royal Society (see Mather, 1714)—the first publication on American fossil vertebrates, but one more quaint than scientific. Dudley and Mather agreed independently with the Tlascalans, and with medieval European scholars, that such remains were proof of the existence of human giants.

Although his note was not published until after the true discovery had occurred Catesby (1743, II, Appendix, p. vii) records finds that probably were made in this prediscovery period. He says that vertebrae and other bones of sea animals were found imbedded in the earth in all parts of Virginia up to sixty miles from the sea and that three or four teeth were found at Stono in Carolina. Native African negros pronounced these to be the grinders of an elephant. No date is given by Catesby, but it is probable that these anonymous slaves made the first approximately correct identification of an American vertebrate fossil. The teeth undoubtedly were those of a southern mammoth which was, indeed, a sort of elephant.

These prediscovery finds have great sentimental and literary interest, but they had no scientific result. The temptation to consider them in more detail must be resisted in order to devote adequate space to the true discovery and some of its consequences.

CIRCUMSTANCES OF THE TRUE DISCOVERY

The following account of the background of Longueuil's discovery is summarized mainly from Ferland (1882) supported by various data in the Canadian Archives and assisted by a similar account prepared by

[1] One of Kindle's examples, the earliest in date, is erroneous. He credits the Indians with discovery of Big Bone Lick because they are said to have guided Croghan there in 1765. As will be shown, Big Bone Lick had been known to and frequented by white pioneers and explorers for years before Croghan saw it.

[2] Including me—I am indebted to Dr. E. H. Colbert for calling my attention to the incident.

Messrs. Regis Roy and Lawrence J. Burpee (personal communications).

In 1736 Le Moyne de Bienville, the founder and governor of New Orleans, was seriously defeated by the Chickasaw Indians (spelled "Chicacha" or "Chicasa" in contemporary French documents). He wrote to France asking that help be sent from Canada. On Feb. 11, 1737, the President of the Council of Marine (in Versailles, France), wrote to Charles de Beauharnois, Governor and Viceroy ("Lieutenant Général pour le Roy") of New France, stating that 450 soldiers were being sent to Bienville from France and directing Beauharnois to send reënforcements from Canada.

A delay of more than two years ensued, but about the end of June 1739 Bienville joined the troops that he had previously sent to Fort St. François, and they then proceeded up the Mississippi by boat to the mouth of the Margot River, near the present site of Memphis, Tennessee. Here a fort was built, called Fort Assumption because it was begun on Aug. 15, the Feast of the Assumption.

In the meantime a Canadian force of about 440 French and Indians had been gathered, and it set out from Montreal between the 16th and 30th of June 1739. This force was commanded by Charles Le Moyne, second Baron de Longueuil. Among his officers (completely listed in Archives Canadiennes, 1907, pp. 454–455) was M. Le Marchand de Lignery and one of the cadets was M. Gaspard Chaussegros de Lery, fils.

Because Longueuil may be called the star and de Lery the juvenile lead of the paleontological drama under consideration, their careers will be briefly summarized before proceeding.[3] Longueuil, born in Canada on Oct. 13. 1687, was the oldest son in a distinguished family. In 1705 he entered the King's service as a midshipman at Rochefort, France. Having passed successively through the grades of ensign, lieutenant, and captain, he was given the important post of of commandant of Fort Niagara in 1726. Returning to Montreal, he became a major in 1733 and a Knight of St. Louis in 1734. This was his rank and his age was 51 when he set out against the Chickasaws in 1739. As will be seen, he went to France in 1740, and on his return to Canada he became King's Lieutenant at Three Rivers. In 1749 he was made Governor of Montreal and retained this post, one of the most important in the French colonies, until his death in 1755.

Gaspard[4] Chaussegros de Lery, born in Quebec July 20, 1721, was the son of an engineer (we would say civil and military engineer) of the same name and was trained in his father's profession. He was not yet quite 18 years of age when he was sent with Longueuil, with instructions to survey the route and to assist in laying our fortifications, emplacements and roads for the attack on the Chickasaws. He was highly commended for his success in these activities, which initiated a brilliant military and engineering career. Fighting against the English, he became a captain and received the Cross of St. Louis. After the fall of Montreal he went to Europe, where he suffered some tribulations incidental to the disturbed times, but returned to Quebec in 1764 and was occupied in Canada with mapping, building, and his eighteen children until his death on Dec. 11, 1797.

In 1739 the Canadian expedition proceeded south of Lake Ontario and then of Lake Erie as far as Lake Chautaugua ("Tchatakoin" in the French archives), which was reached late in August. They then turned southward to the Allegheny and followed it to the Ohio, near the place where Fort Duquesne later stood and Pittsburgh now stands. Hence they descended the Ohio to the Mississippi and the Mississippi to Fort Assumption, where they joined the Louisianian troops under Bienville and other troops that had just arrived from Illinois under M. de la Buissonnière.

Even with this combined force, great for that place and time, active operations against the Indians did not begin until February of the following year (1740). Then the business was soon concluded, peace was signed in April, Fort Assumption was razed, and the forces dispersed to their several places of original departure. Longueuil, how-

[3] On Longueuil see Jodoin and Vincent, 1889, and on de Lery see Daniel, 1867. Neither of these laudatory biographies includes any mention of the fossil discovery.

[4] Or Joseph-Gaspard.

ever did not return to Canada with his troops but entrusted his report to M. Le Gardeur de St. Pierre and descended the Mississippi to New Orleans with his officer M. de Lignery (or Ligneris—like many names of the period it is differently spelled in different documents). This action, which must have been somewhat irregular, was explained to the President of the Council of Marine by Bienville, it was approved, and Longueuil was given permission to go to France from New Orleans, which he did toward the end of 1740.

THE DISCOVERY

Historical accounts of this expedition against the Chickasaws, like those combined and paraphrased above, do not mention the incident, but from evidence now to be cited it is certain that fossil bones were found by Longueuil's party while descending the Ohio in the latter part of summer, 1739.

The previously published evidence consists of a map by the French cartographer N. Bellin, Engineer of the Marine, engraved and published in Paris in 1744, and of a statement in a paper by Daubenton, read to the French Royal Academy on Aug. 28, 1762, and printed in 1764. Although the incident is repeatedly, if only briefly, mentioned in later publications considerable study of these supports belief that they were all based directly or indirectly on one or the other of these sources, but apparently not on both. Most literary or at least non-paleontological historians have derived information from Bellin, whether or not at first hand, and most paleontological historians from Daubenton.[5] Bellin's and Daubenton's own sources were independent.

The Bellin map (fig. 1) has the notation "Endroit ou on a trouvé des Os d'Elephant en 1729" ("Place where elephant bones were found in 1729") on the south side of the lower course of the Ohio ("Oyo" or "Belle") River, nearly opposite but somewhat upstream (east) from the notation "Saute ou chute d'Eau" ("Waterfall"). No precise spot is marked. The "falls" are surely the Falls, or Rapids, of the Ohio, a famous landmark throughout the history of river transportation, at the present site of Louisville, Kentucky.

The most pertinent part of Daubenton's statement is as follows:

> M. le baron de Longueuil sortant du lac Érié en 1739, avec un gros parti de François & de Sauvages, descendit sur ses canots la rivière Oyo jusqu'à son embouchure dans le Mississipi, à trente-cinq lieues au-dessous des Illinois: tandis qu'il étoit campé a moitié chemin sur l'Oyo, quelques Sauvages étant à la chasse, trouvèrent les ossemens de trois gros animaux sur le bord d'un marais, & apportèrent au camp le fémur dont il s'agit & des défenses que l'on crut être d'elephant, & que M. de Longueuil apporta en France en 1740. . . . M. du Hamel, de cette Académie, m'a dit que M. de Longueuil avoit apporté du Canada de très-grosses dents molaires avec le fémur & la defense, dont il vient d'être fait mention: il y a trois de ces dents au Cabinet du Roi.
>
> (The Baron de Longueuil, leaving Lake Erie in 1739, with a large party of French and Indians, went down the Ohio River in canoes as far as its junction with the Mississippi, 35 leagues below the Illinois. While he was camped halfway down the Ohio, some Indians who were out hunting found the bones of three big animals on the edge of a swamp and brought into camp the femur in question and some tusks that were believed to be those of elephants and that Longueuil brought to France in 1740. . . . M. du Hamel, of this Academy, told me that Longueuil brought from Canada[6] some very large molar teeth with the femur and the tusk just mentioned. There are three of these teeth in the King's Cabinet.)

Bellin said that his information on the Ohio River was derived from de Lery. It is certain that his immediate source, hitherto unpublished, was a manuscript map that is, or was before the present war, in the "Depot des Cartes et Plans de la Marine, Service Hydrographique," in Paris, where it was classified as "4044C. No. 54" (see Roy, 1911, p. 273). A photographic copy of this unique and priceless document was obtained for the Public Archives of Canada, and this was duplicated for my use by the Archives, through the kindness of G. Lanctot, Deputy Minister. (See fig. 2.)

According to its legend, this manuscript map was drawn up

> à l'estime par le Sr. delery fils & dessiné par le Sr. de Mandeville en 1740 (by estimate [or ap-

[5] As a matter of fact, the greater number of historians in both categories have not mentioned Longueuil's discovery at all. Of course this majority is not in question in this discussion of sources.

[6] Although now in Kentucky, the region in question was then claimed for and considered part of Canada.

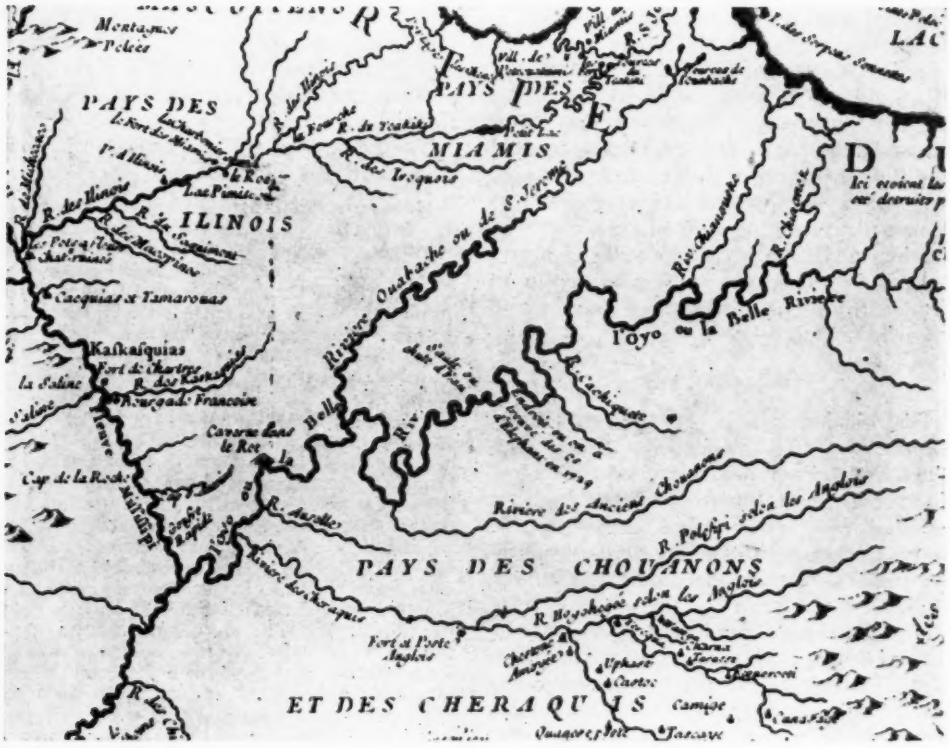

FIG. *1*—Part of the map of Louisiana, etc., published by Bellin in 1744. This part shows the middle and lower Ohio, the Wabash, and part of the Mississippi. The "Endroit ou on a trouvé des Os d'Elephant en 1729" is marked in a loop of the Ohio near the middle of the figure. (From a copy in the New York Public Library).

proximation] by de Lery, Junior, and drawn by de Mandeville in 1740).

This Mandeville (a surname) was Philippe, sieur de Marigny, then a lieutenant with the Louisiana troops (Regis Roy, pers. comm.). The manuscript bears the following more explicit but atrociously spelled legend for the fossil locality:

> En droit ou yl a Etté trouvé Les Eaux [*sic!*] de plusieurs Elephans pard. L'armée du Cannada Commandé pard Mr Le Baron de Longuille et ou jl a fâit mettre Les Armes du Roy En 1739. (Place where the bones of several elephants were found by the Canadian army commanded by the Baron de Longueuil and where he planted the arms [or flag] of the King in 1739.)

The exact spot is indicated by a letter "A" on the southeast (now the Kentucky) side of the Ohio near the extremity of a northward loop of the river, the second and larger of two such loops northeast or upstream from the indicated site of the falls ("Chute" marked on the manuscript).

If any doubt remained, this contemporary document completely establishes the fact of the discovery.

Although prepared eighteen years after the publication of Bellin's map and seven years after Longueuil's death, Daubenton's statement is both more circumstantial and more correct (at least as to date) than Bellin's. Daubenton apparently obtained these data from du Hamel, but the source of the latter's information is not known. The lapse of twenty-two years since Longueuil took the bones to France does not preclude the obtaining of the facts from someone who talked with him on that occasion, and it is also probable that some written notation was preserved with the specimens in the Cabinet du Roi. In any case, it may be taken that du Hamel did have some reason-

ably accurate source, especially since he did not repeat the earlier error of Bellin.

THE DATE

From the facts already given, it is abundantly clear that the date of the discovery was 1739, not 1729 as given by Bellin, and it is unnecessary to belabor this point. It is, however, necessary to emphasize it, because the date 1729 has often been repeated and is deeply embedded in the literature.[7] If any further proof were needed, it would be provided by the fact that de Lery, correctly credited by Bellin with mapping the site at the time, was only eight years old in 1729.[8]

THE DISCOVERER

No source attaches a personal name directly to the discovery. We are told (ms. map) that the bones were found by the army commanded by Longueuil, or (Daubenton) that they were found by Indians hunting for (and therefore also attached to and forming part of) that army. Thus no statement can be made as to the particular individual who first laid eyes on these fossils, but they were found by a party of which Longueuil was the responsible head and Longueuil personally escorted the bones to France (Daubenton), which means, incidentally, that he must have cared for them and had them carried and preserved all the way through the Chickasaw war and over the whole perilous course from the site of discovery to New Orleans. It seems proper to credit the discovery to Longueuil.

It is true that Daubenton implied, without being wholly explicit, that only Indians visited the fossil site and saw the bones in place, but in this he was guilty of special pleading in defense of an *a priori* thesis and his implications must be judged in that light. Daubenton's thesis was that the femur belonged to an elephant of the living species. He observed that the molar teeth could not be those of an elephant. He therefore wished to prove that the femur and the teeth were not from the same animal. To support this he wished to believe that only Indians had seen the skeletons in their entirety, because the evidence of a "savage" as to association could be summarily rejected, while that of a cultured white man could not. Daubenton was wrong: teeth and bones did belong to one species, the American mastodon. His unsupported and ex-parte testimony as to who did or did not see the bones in place can be granted no weight.

As a simple matter of probability, it is unlikely to the point of complete incredibility that anyone who subsequently took such a strong and practical interest in the bones as did Longueuil and who, like him, must have been within an hour's walk of the locality, at most, would have failed to visit that locality. (It is even a physical possibility, as Mr. Regis Roy has suggested in correspondence, that Longueuil returned to the site during the long months of waiting at Fort Assumption before the campaign really opened, but there is no concrete evidence that he did so.)

THE LOCALITY

As far as I have found, every author who has mentioned Longueuil's discovery and who knew of Big Bone Lick has stated, without expressed doubt or evidence, that Longueuil's locality was that later called Big Bone Lick. The assumption is not unreasonable, on the basis that Longueuil's discovery was in the same region as Big Bone Lick, that the latter became, within less than thirty years of Longueuil's expedition, a source for a great number of bones similar to those found by him, and that no comparably rich deposit has been found elsewhere in that region. Nevertheless careful study of the data now brought together for the first time casts some real doubt on this conclusion.

From Daubenton we learn only that

[7] It is, for instance, stressed in Jillson's excellent study (1936), and his authoritative annotated bibliography "corrects" all the references to the date 1739. In other publications Jillson had given the correct date, however, and he was following correct procedure in adopting the date given by the oldest authentic document available to him.

[8] This is perhaps complicated by the fact that another Chaussegros de Lery, father of our de Lery, was also a cartographer and was, of course, mature in 1729. There is, however, no possible doubt that the son, not the father, is here in question. For instance (Archives Report, 1905, p. 276) the President of the Council of Marine wrote on May 2, 1740, to Chaussegros de Lery expressing satisfaction that his, de Lery's, *son* had accompanied Longueuil.

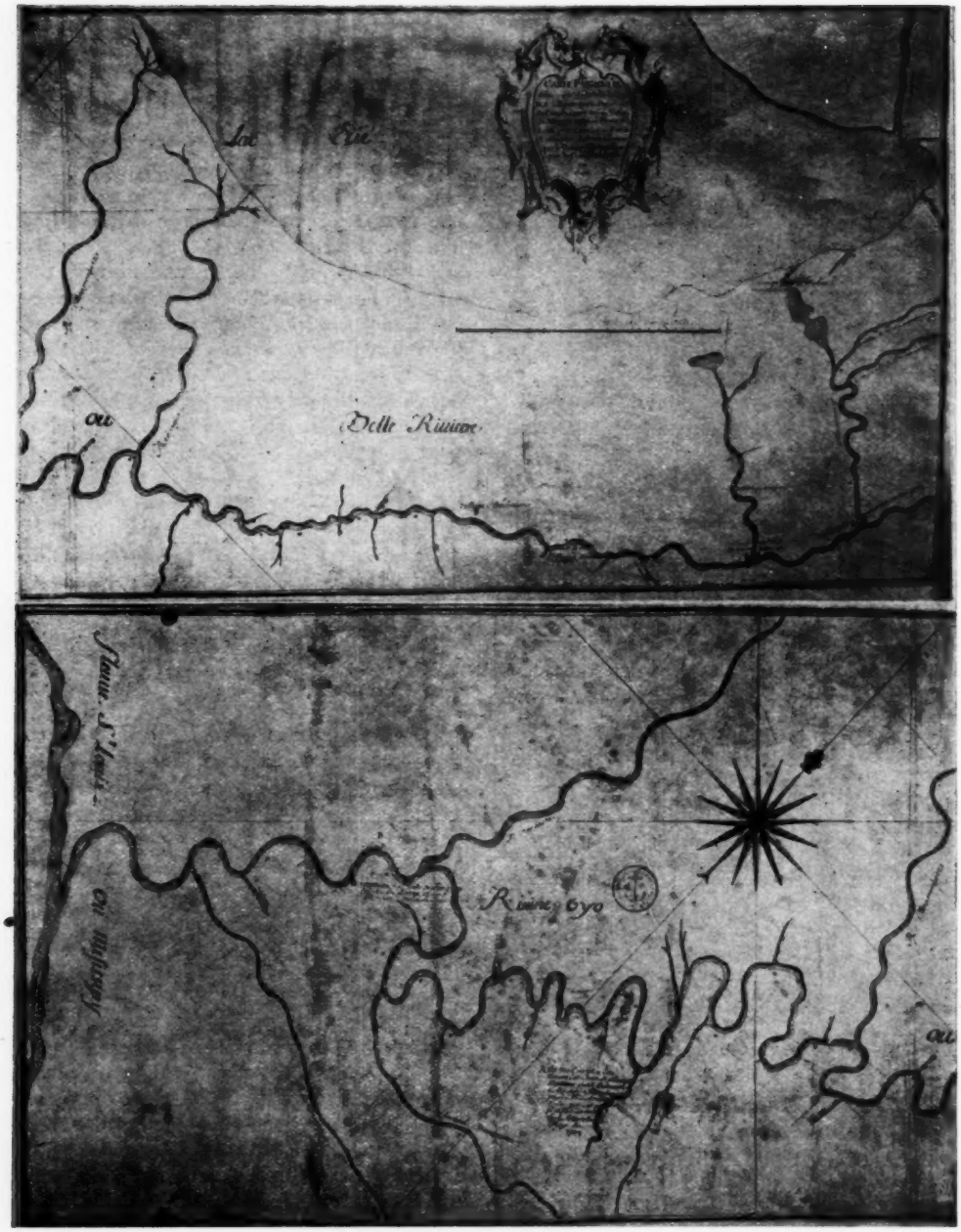

FIG. 2—Manuscript map of the Ohio River drawn by Mandeville in 1740 from the survey of de Lery in 1739. The locality where Longueuil's party found mastodon bones in 1739 is marked "A," inside a northward loop of the Ohio, just to the right of the south ray from the compass, in the lower section. The original manuscript is on one sheet but has been photographed in two slightly overlapping sections. It extends from Niagara, upper right, to the Mississippi, lower left. Original in the Marine Archives, Paris. Photograph from the Public Archives of Canada.

Longueuil's collection was made about half-way down the Ohio on the edge of a marsh. Big Bone Lick is, indeed, on (near) the Ohio about half-way from Pittsburgh to Cairo and it was a marsh in the 18th century, but the statement is too vague to indicate a precise locality.

A precise locality is, however, indicated on Mandeville's manuscript map made from de Lery's approximate traverse. The accuracy of that map is not great, but long study and comparison convince me that within the broad limits of accuracy here displayed the locality later called Big Bone Lick would not intentionally have been placed at the "elephant bones" locality of the map. By any possible identifications of the windings of the Ohio or relation to fixed landmarks, the manuscript map certainly shows Longueuil's fossil locality considerably farther southwest, down the Ohio, than it would, if correct by its own standards, show the locality of Big Bone Lick. Longueuil's locality appears on this map to be approximately in what is now Trimble County, or one of the more nearly adjacent counties, in Kentucky. A certain landmark is provided by the Falls of the Ohio. With less certainty, the Licking River is probably the "Kachiqueto" of the manuscript map.[9] Whatever possible identification of this and adjacent streams is adopted, the "elephant locality" is shown definitely farther southwest than the site of Big Bone Lick.

It seems, then, either that the manuscript map, the only contemporary record, was definitely in error when made and by its own standards, or that Longueuil's locality was not Big Bone Lick. On the evidence now obtainable, which results from such extensive search that it is unlikely to be supplemented unless by accident, a clear decision between these alternatives is impossible.

The first alternative, that the map is in error and that Longueuil did find Big Bone Lick, may be supported by the fact that the actual drafting of the map occurred some months after the event and was by a man who had not been at the locality. This evidence is, however, largely invalidated by the certainty that the map was drawn up from de Lery's notes and the great probability that it was drawn up in actual conference with de Lery. It is also probable that Longueuil personally examined and approved the map. De Lery and Longueuil did know the site. The manuscript map does not indicate merely a region, as does Bellin's, but one particular spot.

The other valid argument in favor of the equation of Longueuil's locality and Big Bone Lick is the absence of likely alternatives. There are other marshy places along and near the Ohio between Big Bone Lick and Louisville, but as far as I know mastodon bones have not been found in them, and it may be supposed that Longueuil's locality must have been fairly rich and obvious at the time. Yet it has happened, and it could have happened here, that all the surface bones have been picked up without much or any scientific record, or have disintegrated, and that a fossil locality once rich has been lost. Big Bone Lick, itself, formerly one of the richest and most obvious of known fossil localities, has no bones exposed at the present time and has yielded very little in the last seventy years. There is no geological reason why mastodon remains might not occur sporadically almost anywhere between Covington and Louisville. We have also the Indian evidence, reported by Wright to Bartram in the letter given on a later page, that such bones were not, at about this time, confined to a single locality but occurred widely over this region.

It would be worth while to test the hypothesis that Longueuil's discovery was made somewhere around Trimble, rather than in Boone County, and to search for mastodons there. As far as I know, no such search has been systematically made.

THE LONGUEUIL COLLECTION

Longueuil's claim as the true discoverer of North American fossil vertebrates depends more on the results of his discovery than on its absolute priority. It is therefore proposed to follow more briefly some of the

[9] Jillson (1936) formerly identified the "Cachiquete" of Bellin's map, which is the Kachiqueto of the Mandeville-de Lery map, as the Kentucky. This would make identification of Longueuil's locality with Big Bone Lick still less probable. Now, after examining the Mandeville-de Lery map, Jillson (pers. com.) considers the Kachiqueto to be the Licking, the view adopted here, partly on his authority.

subsequent history of his collection. That he did make a collection, contrary to some statements in the literature, and that he took it to France have already been demonstrated by the evidence of Daubenton, which on this point can hardly be controverted. That collection included at least three molar teeth, a tusk and a femur (listed by Daubenton, who hints that there may have been more teeth in the lot). One of the molars was figured by Guettard (1756, paper read in 1752), who did not hazard any guess as to its nature but who must be credited with publication of the first illustration of a North American fossil vertebrate. He was vague as to the origin of the tooth, but from what is now known it may confidently be claimed that this molar was from the Longueuil collection. It is possible but improbable that other, similar specimens had then been received in France.

Daubenton's paper (1764, read in 1762), already repeatedly mentioned, gave a figure comparing the femur collected by Longueuil with those of a Siberian mammoth and of a recent elephant. He concluded that all belonged to the same species. That conclusion was incorrect, but not grossly so because it did establish the general affinities of these animals. Daubenton's paper and this illustration in it were extraordinarily important in the history of paleontology because they established and exemplified the correct basic procedure for identifying fossils, a fundamental discovery often credited to Cuvier a generation later. Less happily, Daubenton concluded that the molar teeth in the Longueuil collection were those of a gigantic hippopotamus. From the figures and descriptions it is clear that all of Longueuil's specimens were of the animal later identified as the American mastodon, *Mammut americanum*. Daubenton's observations and influences were repeated in some of his later publications as well as in Buffon's, which, in this respect, were based on or quoted Daubenton.

Soon after Daubenton's first publication (1764) on Longueuil's collection, around and after the date 1767, other, larger collections of remains of the American mastodon were received in Europe and thereafter study was not based only or principally on Longueuil's material, but the latter was still used and it was referred to by Cuvier (e.g. 1834), whose voluminous and epochal publications thus owe something to this earliest of American collections. After Cuvier, these historically oldest specimens seem to have dropped from explicit attention, but it is quite possible that some of them are still preserved in Paris, a point that can not be checked at present (1941, during the German occupation of Paris).

DISCOVERY OF BIG BONE LICK

In view of the possibility that Longueuil did not discover Big Bone Lick, as previously supposed,[9] it becomes necessary to consider who did if he did not. Most of the known facts are presented with a full bibliography by Jillson (1936), and they therefore need only short summary here, with mention of a slight difference of opinion and with a few additional data.

Although not published at the time, the next known reference to fossil bones in this part of the world was by Christopher Gist (written in 1751, published in 1893). In 1751 he was going down the Ohio valley (with horses, not down the river by canoe) and on Wednesday, March 13, of that year, as related in his diary, he met one Hugh Crawford and two men "belonging to" Robert Smith, who had a house below the mouth of the Miami (and hence near Big Bone Lick). These men, at the instance of Smith, gave Gist two teeth of a large beast "from towards the Falls of the Ohio," one of which Gist delivered to the Ohio Company. Smith told Gist that about seven years before, that is about 1744, teeth and bones of three large beasts were found in a salt lick or spring on a small creek that runs into the south side of the Ohio

> about 15 M below the Mouth of the Miamee River, and 20 above the Falls of the Ohio.

Like other distances reported by Gist, these are radically wrong in some way because the distance from the mouth of the Great

[9] That is, by those who knew of Longueuil at all. No earlier discoverer has been claimed. In what appears to be the only paper exclusively devoted to the discovery of Big Bone Lick, Kindle (1931) erroneously claims this honor for Croghan. Croghan's true position in the matter will later be briefly mentioned.

Miami to the Falls is some three times as far as stated.[10]

Again certainty is impossible, but it is probable, more probable than for Longueuil's locality, that the teeth here in question were from Big Bone Lick. That lick is about 25 miles below the mouth of the (Great) Miami, rather than 15 as reported by Gist, but the error is not unreasonable, and no other known lick agrees as well with the indications given. It is more than 75 miles above the falls, as against Gist's 20, but Gist's total distances are grossly erroneous in any case and distances from the Miami, where he had been, are likely to be less inaccurate than those from the falls, where he did not go and of whose location he seems to have had only a vague and somewhat timorous notion (hostile Indians were reported there).

As quoted by Gist, Smith did not say who had found the fossil locality in question. The language does not suggest that the discoverer was Smith, himself. The date, ca. 1744, implicit in Smith's "about seven years ago" is only five years after the known visit of Longueuil, whose soldiers must also have passed here on the return trip in 1740. Smith said that remains of "three large Beasts" were found and Daubenton said almost identically that Longueuil's Indians found remains "de trois gros animaux." On other grounds, the inference is not probable but the coincidence is curious and it is remotely possible that Smith was actually referring to Longueuil's discovery.

I do not know what happened to the tooth given to the Ohio Company. It may have been one of those that turned up in London not long after, with vaguely recorded or unrecorded origins.

[10] A few days later, on March 18, Gist visited and described in his journal a lick on what he called "the lower Salt Lick Creek." Jillson (1936, pp. 5 seq.) quotes the pertinent passages in full and concludes that the lick seen on March 18th was Big Bone Lick. But if Gist had visited the locality whence came the teeth just received with such interest, it is strange that he did not know or note this fact. His editor, Darlington, considered Gist's route with care and concluded that his lower Salt Lick Creek was Salt River and his lick that now called Bullitt's Lick, Bullitt County, far from Big Bone. Jillson (pers. com.), on the other hand, points out that Gist's slow mode of travel would make it almost impossible to reach Bullitt's Lick in the stated time.

During the 1850's and early 1860's there was considerable movement into and through this region. Many persons doubtless visited Big Bone Lick during this period, and there is evidence that it was then well known, at least locally, but few records were left, and it is uncertain what collections may have been made or by whom after Longueuil and before Croghan (1766), although it is known that some were made in that interval. As Jillson (1936) shows, the frontiersman John Findley visited the Lick in 1752 and Mary Inglis escaped from the French and their Indian allies there in 1756. Her captors had gone there to boil for salt so that the Lick was frequented for that purpose at least as early as that date.

Growing interest in Big Bone Lick and its fossils and perhaps the first stirring of definitely scientific concern with them by strictly American naturalists are demonstrated in a letter written in 1762 by James Wright to John Bartram. This must be the James Wright of Susquehanna, Delaware County (Pennsylvania), who was elected a member of the American Philosophical Society in 1768. John Bartram, probably the most famous of American colonial naturalists, was a charter member ("Old Member under the Original Plan, 1743") of the same society (actually organized in 1742 and an outgrowth of Franklin's Junto, 1727). He was primarily a botanist, but like other naturalists of the time he considered everything in nature within his field of study, and it is not surprising to find him enquiring about fossil bones. It is probable that the information was desired for communication to this oldest of American scientific societies, but its minutes prior to 1768 have not been preserved. Bartram was also in touch with numerous Old-World naturalists, particularly Collinson, London, who took a very active interest in Big Bone Lick fossils in the later 1760's.

The letter is in the British Museum (Additional Mss. 216 48, ff. 333–4) and is copied in the Public Archives of Canada (Bouquet Papers, vol. 18–2, pp. 379–82). It is not cited in Jillson's almost exhaustive history of Big Bone Lick and does not appear to have been known to paleontological historians. For this reason and because of its inherent interest it is given in full, from a transcript

kindly supplied by Mr. A. J. H. Richardson, who brought the letter to my attention.[11]

Respected friend

Pursuant to thy request, I have made as particular an Enquiry relating to those bones thou mentions, as I possibly Could, from two Sencible Shawanese[12] Indians, Assisted by an Interpreter, And the Substance of what they Say is as follows —the place where they lye is about 3 miles from the Ohio, salt & moist, as well as I could judge by their description of it seems to contain 30 or 40 Acres, in the Midst of a large Savannah, 4 days Journey Below the lower Shawanese town,[13] on the East Side of the river, that there appear to be the remains of 5 Entire Sceletons, with their heads All Pointing towards Each other, And near together, supposd to have fallen at the same time; when they were desired to describe their several parts, they began with their heads, of which two were larger than the rest, one of these, they said a Man Could but Just Grasp in Both his Arms, with a long Nose, And the Mouth on the under side, they next mentiond the shoulder blade, which when set on End, reached to their Shoulders, And they were both tall men, What they Call'd the Cup (or socket) of this bone, was equal in size to a large bowl, the thigh bone when broke assunder, would admit of a little boy's Creeping into it—they were askd if they had seen those long bones they Call'd horns, they Answered they had, And by the distance from where they stood to the door, Showd them to be 10 or 12 feet long, And added that by the Bones, they Judged the Creature when Alive must have been the Size of a Small House, pointing from the Window to a Stable in Sight;—I askd them if the Place where they lay was Surounded with Mountains, So as to admit a probability of its Ever having been a lake, they Answered, the place was salt and Wettish, And by having been much trod & Licked, was somthing lower than the adjacent land, which however, was so level, to a prodigious Extent, that the lick, as they Calld it, Could never have been coverd with water; And that there were many roads thro this Extent of land, larger & more beaten by Buffolas and other Creatures, that had made them to go to it, than any Roads they saw in this Part of the Country on being Questioned if they had seen such bones in Any other place, they said they had seen many such, Scatterd here & there in that large tract of land mentioned before, some upon the Surface, and some Partly burned [buried?], but all much more decay'd by time, then those they had been describing, and not Any Entire Sceleton; I Askd if they had Ever heard from their old men, when these 5 were first observed, of if they, or their fathers, had Ever seen any such large Creatures living, as these bones were supposd to have been a part of, they Answered they had never heard them spoken of, other then as in the Condition they are at present, nor ever heard of any such creature having been seen by the oldest Man, or his father—that they had indeed a tradition, such mighty Creatures, once frequented those Savannahs, that there were then men of a size proportionable to them, who used to kill them, and tye them in Their Nop-pusses [knapsacks] And throw them upon their Backs As an Indian now dos a Deer, that they had seen Marks in rocks, which tradition said, were made by these Great & Strong Men, when they sate down with their Burthens, such as a Man makes by sitting down on the Snow, that when there were no more of these strong Men left alive, God Kiled these Mighty Creatures, that they should not hurt the present race of Indians, And added, God had Kill'd these last 5 they had been questioned about, which the Interpreter said was to be understood, they supposed them to have been Killd by lightning—these the Shawanese said were their traditions, and as to what they knew, they had told it—the Man who Interpreted, was well Acquainted with their language, and as I have known him from a boy, I am Confident he would do it faithfully, I shal be pleas'd if what smal Information I have gain'd wil be agreable to thee, And shal be glad to oblige thee at any time to the Utmost of my Power,

I am thy Assured friend
James Wright

August 22nd 1762
John Bartram

As Barton later commented, it is noteworthy that these Indians clearly distinguished fact from fiction. They knew that there was no reliable testimony or memory of the animals in life. This contrasts significantly with legends later given by Jefferson, also as coming from the Shawnees, and believed by him to prove that the species of animals represented by the bones was still alive.

[11] The substance of this letter, rephrased in the third person, was published by Benjamin Smith Barton, another famous member of the American Philosophical Society, in 1804, and hence was picked up and summarized by Cuvier. Barton did not give the date of the incident explicitly, and he stated that Bartram's correspondent, designated only as "James" in the manuscript in Barton's hands, was James Logan, rather than James Wright as the original letter proves. Barton gives the additional information that Bartram's interest was aroused by a letter to him from Colonel Bouquette saying that some Shawnee Indians had brought a tooth (probably a molar) and a piece of tusk to Pittsburgh. It is somewhat curious to find the Indians as sole authorities in this incident, when a number of whites had certainly already visited the Lick.

[12] [Shawnee, also called Shawnnesse, etc., by contemporary English writers and Chouanons, etc., by the French].

[13] [Near the junction of the Scioto with the Ohio; from here to Big Bone Lick would be 125 miles or more, a considerable but possible four day journey].

In 1765 George Croghan, an unusually capable Indian Agent, visited Big Bone Lick and wrote a brief description of it in his journal. He collected a tusk and some bones but his party was later captured by hostile Indians, he was wounded, and the collection was lost. In the following year, freed from captivity and recovered from his wound, he again visited Big Bone in company with Captain Harry Gordon, who wrote another and somewhat more detailed account of the lick. On this occasion Croghan made another collection, which was successfully removed and sent to London to Lord Shelbourne and Benjamin Franklin. This collection played an important part in the subsequent development of paleontology, but its later history need not be followed here. (Croghan's journal of 1765 was published by Featherstonhaugh, 1831, and the pertinent parts of it, together with those of Gordon's journal, by Kindle, 1931, and Jillson, 1936.)

When Croghan's collection arrived in London, there was already

> a considerable quantity of elephants teeth . . . from the banks of the Ohio

in the Tower (the King's collection) Hunter, 1769). The collector of these is not known. Various other, more isolated specimens had also been taken to England by this time, for instance a molar (mastodon, as all these early specimens appear to have been) in the possession of Earl Bute (Collinson, 1768b) and a small tusk in the hands of a Captain Owry of Hammersmith, who had served in America (Collinson, 1768a).

Now the thin trickle of fossils collected in America had become a stream that continued to flow and to increase until, in the following century, it became a flood. A study of the beginnings of this phenomenon need go no farther. As to the specific question of who discovered Big Bone Lick if Longueuil did not, the facts so far known do not permit crediting this discovery to any one person or attaching a particular name to it. Whether his locality was Big Bone Lick or not, Longueuil was the first discoverer and collector of North American fossil vertebrates, from the viewpoint of scientific history.

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STROPHOMENACEA OF THE CEDAR VALLEY LIMESTONE OF IOWA

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ABSTRACT—Fourteen species of brachiopods from the Upper Devonian Cedar Valley limestone are described and illustrated, ten of them as new. Four families are represented: Chonetidae by *Chonetes;* Productidae by *Productella* and *Strophalosia;* Orthotetidae by *Schuchertella;* Stropheodontidae by *Pholidostrophia* and *Leptostrophia.* The genera are discussed at length and one new genus, *Devonoproductus,* is proposed.

IN THIS PAPER are described the remaining species of the Strophomenacea occurring in the Cedar Valley formation. The Stropheodontae, numbering 17 forms, have been discussed previously. The spine-bearing genera, *Chonetes* and *Productella,* in the present group of brachiopods are the most numerous specifically. This abundance seems to foreshadow the great increase in productids in later strata and to indicate the relatively late Devonian age of the formation. The remaining genera have one or two species only. Individually most species are among the more uncommon members of the Cedar Valley fauna. *Chonetes* alone has one species abundantly represented in a few small areas.

Few of these brachiopods are found elsewhere in strata of like age in adjacent states, and consequently their value for correlation, other than negative, is relatively small. *Chonetes schucherti* and *Pholidostrophia iowensis* are found in zone C of the Milwaukee formation at Milwaukee. Their weight is added to that of others in supporting the correlation of the Rapid member of the Cedar Valley with the Milwaukee formation.

Pholidostrophia iowensis has been reported from the Hamilton in various localities in the eastern United States by writers who follow Schuchert's placing of *Stropheodonta nacrea* Hall in synonymy with it. In the writer's collection are numerous *Pholidostrophia* from a number of Hamilton localities, and most of them are specifically distinct from *Pholidostrophia iowensis.* The form in the Silica shale at Silica, Ohio, is much larger, heavier, and more geniculate near the front margin. Those in the upper Bell shale at Rockport, Michigan, tend to be larger, thinner and flatter. Specimens from the Feron Point shale near Rockport are larger. Others from localities in New York are considerably larger and differently shaped.

Leptostrophia fragilis is similar to the *Leptostrophia* in the Silica shale, which also has every sixth to eighth costa slightly enlarged. But that species in addition has a high, narrow, convex deltidium, while the Iowa form has a deltidium that is flush with the surface of the palintrope and indistinguishable from it externally.

The illustrations are all natural size unless otherwise noted. Type specimens with the initials S.U.I. preceding their serial numbers are in the collections of the State University of Iowa. Those with M.A.S. are in the writer's collection, which eventually will be placed with that of the University of Iowa. C.H.B. refers to the Belanski collections, now in the University repository.

SYSTEMATIC DESCRIPTIONS

Order PROTREMATA Beecher, 1891
Superfamily STROPHOMENACEA Schuchert, 1896
Family STROPHEODONTIDAE Caster, 1939
Subfamily STROPHEODONTINAE Caster, 1939
Genus LEPTOSTROPHIA Hall and Clarke

The Cedar Valley species of brachipods associated with this genus have characteristics similar to *Stropheodonta perplana* Hall and apparently belong to the *perplana* complex of Caster. It is not clear, however, whether they should be placed in the genus *Protoleptostrophia* Caster. Since this group of shells is under revision by that author we

are using the generic term *Leptostrophia* in its old inclusive sense.

LEPTOSTROPHIA FRAGILIS Hall
Plate 6, figures 5–7

Strophomena (Strophodonta) fragilis HALL, *1857*, New York State Cab. Nat. History, Ann. Rept. 10, p. 143.
Strophodonta fragilis, HALL, *1858*, Geol. Iowa, vol. 1, pt. 2, p. 496, pl. 3, fig. 6 a–c.
Strophodonta perplana HALL, *1867*, New York Geol. Survey Paleontology, vol. 4, pp. 98–101, pl. 17, figs. 1f, 1g, 1o. Not pl. 17, figs. 1 a–e, i–n; pl. 11, fig. 22; pl. 12, figs. 13–15.
Strophedonta perplana, CLELAND, *1911*, Wisconsin Geol. Survey Bull. 21, p. 89, pl. 18, figs. 1–4.
Strophedonta (Leptostrophia) perplana, HALL and CLARKE, *1893*, New York Geol. Survey Paleontology, vol. 8, pt. 1, pl. 15, figs. 4, 5, 8. Not figs. 1–3, 6, 7, 9–13.

Shell subquadrate to semielliptical in outline, thin, flattened, wider than long, with rounded anterolateral margins, and with the hinge line equalling or less than the greatest width. Dimensions of two hypotypes: length, 24 and 22 mm.; width, 30 and 32.5 mm.

Pedicle valve flattened, only slightly convex, highest in the umbonal region; beak small, projecting a little beyond the hinge line; palintrope about a millimeter high beneath the beak, and of nearly equal height to the extremities, flat, inclined slightly to the plane of the valve; deltidium indistinguishable from the palintrope. In the interior are two large pyriform muscle scars separated by a slight median ridge; the posterior boundaries of the scars are distinct due to the strongly divergent ridges extending from the beak; the anterior boundary is indistinctly marked. The remainder of the interior of the valve is marked by numerous radiating grooves and minute papillae, which are considerably larger posterior to the muscle area.

Brachial valve gently concave to flat; beak indistinguishable; palintrope low and inclined to the plane of the valve.

Surface of both valves marked by numerous fine costae, which increase by imbrication on the pedicle valve and by division on the brachial. The costae are crossed by crowded fine concentric striae in such manner as to give them a rugose appearance or a beaded effect. Every fifth or sixth costa is larger and gives the surface a characteristic appearance.

The shells are thin and fragile, and complete specimens are rather uncommon. However, a layer several inches in thickness will occasionally be crowded with valves.

Hall (1857) described this form as a new species and stated that it came from central and western New York; also from Rock Island, Ill., and New Buffalo, Iowa. He did not mention therein the enlargement of every fifth or sixth costa. In 1858 he illustrated specimens from Iowa, and the enlargement of the surface of one of the specimens plainly shows this variation in the size of the costae of the pedicle valve. As far as is known the examples of *Strophondonta fragilis* from western New York were never illustrated, at least under this specific name. Later Hall (1867) united *Strophodonta fragilis* Hall with *Strophodonta perplana* Conrad but illustrated a specimen from Iowa as varying from the typical in possessing every fifth or sixth costa larger than those on either side. This variation seems to be a constant feature of the Iowa examples although sometimes faintly developed, and it is regarded as sufficient to delimit a separate species. The Iowa form of *Strophodonta fragilis* Hall is taken to be typical inasmuch as it is the first and only one illustrated under that name.

Occurrence.—Cedar Valley limestone, in the middle part of the *Atrypa bellula* zone, and as far as known confined to southeast part of the Cedar Valley area; Buffalo, Linwood, Moscow, in Iowa; Rock Island, Illinois.

Types.—Hypotypes, S.U.I. 6-330 and 6-331; M.A.S. 4, 187, 421, and 422.

LEPTOSTROPHIA OCCIDENTALIS
Stainbrook, n. sp.
Plate 6, figures 2–4, 11

Shell large, depressed concavo-convex, semioval in outline, with the lateral margins joining the front margin in a broad curve, wider than long, broadest along the hinge line. Dimensions of the holotype are: length, 32.9 mm.; width, 39.4 mm.; convexity of the pedicle valve, 4.7 mm.

Pedicle valve gently convex, highest in the umbonal region, the surface curving thence gradually and evenly to the anterior and lateral margins, a little more rapidly at first and then gently toward the cardinal

angles and the hinge line; umbonal region low and broadly convex; beak small and projecting a little beyond the hinge line; palintrope flat, highest beneath the beak and maintaining nearly the same height to the extremities, showing no evidence of a deltidium, vertically striated, and situated in the plane of the valve. Internally the cardinal margin is denticulate; the muscle area large, flabelliform, distinctly defined laterally and posteriorly but merged with the remainder of the valve toward the front. The muscle scars are separated by a distinct median ridge and marked by fine radiating longitudinal ridges. The remaining portion of the interior of the valve is distinctly papillated, especially along the posterior margins of the muscle area.

Brachial valve gently concave; palintrope flat, rarely half a millimeter in height, and at right angles to the plane of the valve.

The surface of the pedicle valve is marked by numerous coarse radiating costae, which increase by intercalation and number about six in the space of 2 mm. near the front margin. The intercostal spaces are as wide as or wider than the costae. Numerous small concentric ridges cross the costae and give them a rugose beaded appearance. The costae of the brachial valve are similar but are closer together and are less rugose and angular. Growth lines occasional but may in some instances be strong enough to interrupt the continuity of the costae.

Leptostrophia occidentalis is a more robust shell than *L. perplana* and possesses costae that are more rugose, twice as broad and half as numerous. From *Leptostrophia fragilis*, *L. occidentalis* may be distinguished by its stronger shell, fewer and coarser costae, which are equal in size.

Occurrence.—Cedar Valley limestone. The specimens at hand were collected at Littleton in the *waterlooensis* zone. Several incomplete valves have also been obtained at Brandon and Randalia, Iowa.

Types.—The holotype is S.U.I. 6-333A; paratypes are S.U.I. 6-333 and M.A.S. 10.

Family ORTHOTETIDAE Waagen, 1884, emend. Caster, 1939
Genus SCHUCHERTELLA Girty, 1904

Shells small to large, variable in shape, biconvex, plano-convex, or resupinate, broader than long, with the hinge line less than the greatest width.

Pedicle valve with moderately high umbo and beak, which in some species may be twisted. Palintrope variable in height, divided by a strongly convex deltidium, which completely covers the delthyrium and may be concave at the base; each half is divided into two areas by a line extending from the beak to the hinge line halfway to the extremities. The areas of the palintrope on either side of the deltidium are vertically and horizontally striated. The deltidium and the outer portions of the palintrope are only horizontally marked. Internally the hinge teeth are small, extend but little beyond the hingeline, and are unsupported below by lamellae; only the edges of the hinge plate are thickened. Muscle areas small, indistinctly impressed on the floor of the valve, and separated by a faint median ridge. The remainder of the interior is quite smooth except near the lateral and anterior margins, where the costae are strongly expressed in reverse.

Brachial valve variable, convex, flat to slightly concave. Palintrope low but distinct, divided by a low chilidium, which embraces the cardinal process; each half of the palintrope is divided into regions as in the opposite valve. Internally the cardinal process is short, bifid, with each arm excavated a little on its posterior extremity. From the base of the process on either side a ridge diverges for a distance of one or two millimeters laterally and anteriorly; distally these ridges are expanded a little and posteriorly partially enclose a deep dental socket. Muscle area flabellate, usually not extending to the midlength; scars separated by a distinct median ridge, which is broadly rounded along the summit. The remainder of the valve is generally smooth or marked by obscure ridges and faint papillae. Near the lateral and anterior margins the valve is strongly costate. In neanic individuals the entire interior with the exception of the muscle scars may be costate. The above diagnosis is based on *Schuchertella lens* (White), with *Schuchertella prava* (Hall) and *Schuchertella iowensis* Stainbrook as examples.

Schuchertella was founded by Girty (1904) on *Streptorhynchus lens* White from the Louisiana limestone of Missouri. The char-

acters of the genus were summed up by Weller (1914) who mentioned the biconvexity of the shell and the absence of dental lamellae as outstanding. These two characters he stated "as far as has been observed are always associated." The genus as thus defined is closely related to *Schellwienella*, which differs in possessing dental lamellae and a resupinate shell.

Three species of *Schuchertella* have been examined to determine if external characteristics can be relied on to distinguish the genus and if the external features correlate with those displayed internally. *Schuchertella lens* (White), the genotype of *Schuchertella*, is biconvex and has no internal dental lamellae. *Schuchertella prava* (Hall) is planoconvex, even slightly concavo-convex, and has no internal dental supports. *Schuchertella iowensis*, n. sp. is convexo-concave, even resupinate. From external form alone this last species would be placed in *Schellwienella* without hesitation, but the interior of the pedicle valve shows that the hinge teeth have no supports. In one respect this shell is a *Schuchertella*, in another a *Schellwienella*. This species demonstrates that the external form of the shell alone cannot determine its generic position.

SCHUCHERTELLA IOWENSIS
Stainbrook, n. sp.
Plate 6, figures 8–10, 12–18, 23

Medium to large shells, resupinate, subrectangular in outline, with rounded anterolateral margins and slightly rounded cardinal angles, broader than long, with the greatest width anterior to the hinge line. Dimensions of the holotype and of three paratypes are: length, 24.8, 21.8, 26.3, and 30.7 mm.; width, 32.3, 28.7, 34, and 43.7 mm.; thickness, 8.9, 10, 7.6, and 7.8 mm. A large robust individual measures 29.8 mm. in length (partially restored), 41.5 mm. in width, and 13 mm. in thickness. A large incomplete pedicle valve, partly restored, measures 30.5 mm. in length and 43.9 mm. in width.

Pedicle valve depressed, elevated in the umbonal region, and depressed centrally and anteriorly to a greater or less extent so as to give the valve a resupinate appearance; beak elevated, sharp, projecting beyond the hinge line, generally distorted in most specimens, and laterally directed; palintrope high, as much as 6.5 mm. in some specimens, decreasing rapidly in height to the extremities, posteriorly inclined at an angle of about 45° to the plane of the valve, divided into three areas by two striae, which extend from the beak to points midway between the delthyrium and the extremities of the hinge line, flat or slightly curved, and horizontally striated; delthyrium completely covered by a convex deltidium, which is open a little at the cardinal margin. Internally the hinge teeth are short, strong, extended anteriorly, and unsupprted by dental lamellae, the hinge plate being thickened beneath them. The muscle area is ovate in outline, being broader toward the front, a little depressed below the remainder of the valve, and bordered at the posterolateral margins by low, narrow ridges, which curve anteriorly and inwardly until they become obsolete a short way posterior to the midlength; the diductor scars are separated by a broad, low, rounded, median ridge, which widens posteriorly and disappears at the front border of the muscle area. The floor of the valve beyond the muscle scars is marked by obscure vascular furrows and ovarian pits.

Brachial valve more convex than the pedicle valve, highest at the midpoint, whence the surface curves with moderate rapidity to the margins, depressed and slightly concave toward the cardinal angles; beak scarcely distinguishable; no visible area, or very slightly developed. Internally the cardinal process is formed by two short closely approximated apophyses, which are anchylosed posteriorly to two short outwardly curving lamellae, the whole forming a somewhat crescentic structure, which projects backward beyond the hinge line; dental sockets deep, curved, and bordered anteriorly by the strong lamellae of the cardinal process. The muscle scars are deeply impressed below the floor of the valve; the adductors being pyriform, elongate oval in outline, and extended anteriorly a little beyond the midlength, but indistinctly divided from the remainder of the valve toward the front; between the scars is a low, narrow, rounded, indistinctly defined ridge. The floor of the valve outside the muscle

area shows obscure marks, and near the margins are short radiating ridges.

Exterior of both valves broken by numerous narrow, erect, strong radiating costae, which increase by intercalation and number about five in the space of a millimeter at the anterior margin of a mature specimen. They are subequal in size and are separated by furrows as wide as the costae. Numerous small concentric ridges cross the costae and the spaces between and give the costae a rugose appearance. Prominent growth lines are not uncommon, especially near the front margins of adult shells. In some specimens the surface of the valves is made irregular by strong concentric wrinkles.

Most of the specimens at hand are not well preserved, all but a few being incomplete and more or less crushed. All of them have the resupinate pedicle valve of *Schellwienella* as defined by Weller (1914) and agree with that genus rather than with *Schuchertella* in this respect. None is biconvex. The cardinal area is divided as demanded by either genus. Dental lamellae are not present in the pedicle valve, and the specimens are thus like *Schuchertella*. In Dunbar and Condra's (1932) work on the subfamily Othotetinae, internal characters are considered of more importance, and this form is therefore placed in *Schuchertella*.

This species in the faunal lists of the Iowa Devonian has been referred by authors to the form now known as *Schuchertella arctostriata*, but it differs from that species as defined in Hall's (1867) description and as given in the diagnosis of Grabau and Shimer. Individuals from the Cedar Valley beds attain a width of nearly 2 inches, while specimens from New York as noted by Hall hardly reach three-fourths of an inch. Two specimens from the Cedar Valley beds were compared with type specimens of Hall's *Schuchertella arctostriata* in the American Museum of Natural History and agree well with them in some characters. Though our Iowa form is probably a larger variant, it seems necessary to give it a specific designation. The form described immediately above does not seem to be *Schuchertella chemungensis* since this has the pedicle valve flattened or concave and the brachial valve always convex, in some specimens strongly so.

Schuchertella iowensis is best developed in the *bellula* zone. A single specimen from the basal *independensis* zone may belong to this species. In the *waterlooensis* zone occurs a form which varies in several details. The shells are small, rarely over 1.5 cm. in width, irregular in form, with distorted beaks which in one or two instances display marks that might be interpreted as signs of attachment. The area of the pedicle valve is unusually high and subtriangular. The costae are like those of the larger form but show some tendency to have the fourth or fifth costa larger. In some respects this small shell resembles *Streptorhynchus*, but reference to this genus cannot be verified until better preserved examples are available. A single small example of the internal mold of a brachial valve from the *cranaena* zone also shows a tendency toward variability in size of the costae.

Occurrence.—Cedar Valley limestone in most zones. Examples have been collected at Brandon, Buffalo, Linwood, and various localities near Iowa City, Iowa. A similar form is reported from Wisconsin and Missouri.

Types.—The holotype is S.U.I. 6-323A; paratypes are S.U.I. 6-323 and M.A.S. 3 and 15.

SCHUCHERTELLA? ORTHOPLICATA
Stainbrook, n. sp.
Plate 6, figures 19–22, 24–28

Shell below medium size, nearly planoconvex, semielliptical in outline, wider than long, with the greatest width along the hinge line or a little anterior. Measurements of the holotype and of two paratypes are: length, 11.2, 11.8, and 12.9 mm.; width, 14.6, 14.8, and 18.8 mm.; thickness, 3.2, 3.6, and 5 mm.

Pedicle valve depressed convex, highest in the umbonal region, whence the surface slopes gently and evenly to the lateral and anterior margins; palintrope flat, moderately high at the beak, and decreasing rapidly in height toward the extremities, situated at right angles to the plane of the valve, and divided into regions as in *Schuchertella*, the portion on either side of the deltidium being vertically striated and the remainder horizontally marked; delthyrium completely covered with a convex deltidium, which is open a little at the base. Internally the valve

is marked over much of the surface by deep, narrow, radial grooves, which denote the positions of the plications. The spaces between the grooves are broad and flat. The muscle scars are faintly visible as gently depressed areas in the median posterior portion of the valve. Delthyrial supporting plates are not developed; the edges bordering the delthyrium are thickened but can scarcely be called plates.

Brachial valve flat or very gently convex, slightly elevated in the region of the umbo. Internally the cardinal process is composed of two short, closely united apophyses, which are concave at their posterior extremities. The dental sockets are short, outwardly curved, and bordered anteriorly by high, narrow ridges. Muscle scars small, deeply impressed, separated by a short median ridge, elongate and indistinct toward the front. The remainder of the valve marked by radiating grooves as in the pedicle valve.

Surface of both valves broken by about 28 strong, simple, radiating plications, which are separated by furrows as wide as or wider than the plications and deep and rounded at the bottom. The majority of the plications extend from the beaks to the lateral and front margins, but in some specimens one or two short plications may be intercalated between others. The plications of one valve alternate with those of the opposite valve, and the depressions between are impressed on the interior as broad, flat folds. Minute crowded, rounded, concentric ridges cross the plications and the spaces between.

This form is unlike any other brachiopod in our Iowa Devonian and is not comparable to any other species known to us. Branson in the Missouri Devonian report figures a specimen that agrees with ours in general appearance but comparison shows it to be different. Dr. G. A. Cooper (in correspondence) reports a similar species in the National Museum from Petosky, Mich.

This species is difficult to place either in *Schellwienella* or *Schuchertella*, as it differs in some details from members of each genus. It is similar to both in its orthotetoid shape, in the presence of a convex deltidium, and in the divided nature of the palintrope. It differs from *Schellwienella* in that the shell is not resupinate, the brachial valve is nearly flat instead of convex, delthyrial supporting plates are absent, the exterior is strongly plicate instead of costate, and the interior radially corrugate. It is nearest *Schuchertella*, differing mainly in having a plicate exterior and in being nearly planoconvex instead of biconvex.

In Dunbar and Condra's (1932) key to the Carboniferous genera of the Orthotetinae this species would fall into the group C, i.e., shells with no dental lamellae and no pedicle median septum; and in section II of that group of which the shells are plicate. This would place the shell with *Kiangsella*, from which it differs considerably. If the plicate condition of the shell is a generic character, this species might be made the basis of a new genus. However, for the present it may be placed with *Schuchertella*—a course which would demand that that genus be enlarged to include plicate forms.

Occurrence.—Cedar Valley limestone in the *Atrypa independensis* zone at Independence, Linn Junction, Cedar Rapids, Troy Mills, Vinton, and Solon, Iowa.

Types.—Holotype, S.U.I. 6-328; paratypes, M.A.S. 494, 498, and 1306.

Subfamily PHOLIDOSTROPHIINAE
Genus PHOLIDOSTROPHIA Hall and Clarke, 1892

Shell small to medium, depressed concavo-convex, subquadrate in outline, with broadly rounded anterolateral and front margins, broader than long, with the hinge line equalling the greatest width.

Pedicle valve gently convex, highest at the midpoint; umbo slightly developed, beak small, projecting a little. Palintrope low, flat or gently curved beneath the beak, decreasing in height but little except near the extremities; a little inclined to the plane of the valve. Deltidium indistinguishable from the palintrope and marked by horizontal striae continuous with those on it. Angles slightly extended but seldom preserved completely. On well-preserved examples, at intervals between the beak and the extremities, former extremities of the hinge line project posteriorly and laterally a little somewhat in the manner of spines on

Chonetes. These projections are not homologous, however, with the spines of that genus, as they are not spine-shaped or hollow. The surface is smooth for the most part, but is marked by faint concentric growth striae, occasional strongly developed growth laminae and obscure faint radiating ridges resembling vascular sinuses in their branching, somewhat irregular courses.

In the interior of the pedicle valve the muscle area is deeply impressed on the floor; it is divided by a ridge, which begins in the delthyrial cavity and may broaden at the middle. It bears the adductor scars. The diductor scars are deep and broadly flabellate. The remainder of the valve is generally smooth but is marked by minute scattered papillae, which are aggregated near the muscle scars, and by a few faint radiating linear depressions. Denticulae numerous, moderately strong, present on the major portion of the hinge line but absent at variable distances near the extremities, and smaller near the delthyrial cavity and toward the angles. The denticulae are flat-sided, narrow, elongated at right angles to the hinge line, and slightly inclined toward the sides of the valve. Beneath the surface of the palintrope the translucent shell substance shows that the denticulae are continued internally toward the sharp edge along the upper border. Those on either side of the deltidium attain this edge, but those toward the angles fail to reach it at progressively greater intervals. When the palintrope is carefully sectioned the denticulae are seen to be hollow, as shown by fillings of matrix in several examples. They are not open anteriorly but seem to be hollow posteriorly throughout their extent. Those immediately on either side of the beak appear to reach the surface as tiny pores. These pores are scarcely distinguishable but were first discovered by sectioning. The tubes appear to be homologous with those below the spines of *Chonetes* as demonstrated by Dunbar and Condra (1932).

The brachial valve is shallowly concave, deepest anterior to the middle, whence the surface curves strongly up to the lateral and anterior margins. Surface marked by numerous concentric striae of increment, often by strong laminae of growth. In front of the edge formed by the borders of the palintrope and the surface of the valves of a number of specimens of *Pholidostrophia* sp. there is a series of minute pores, which are slightly elongated and decrease in size toward the angles and toward the chilidium. In specimens of other species the pores are completely or partially closed by a covering of shell. These pores are directly opposite to the tubes visible in the brachial palintrope, which is low, generally about half as high as that opposite and forming an acute angle with it, flat, and with the chilidium indistinguishable.

Internally the brachial valve has a row of sockets immediately anterior to the edge of the palintrope. They correspond in size and shape to the denticulae of the opposite valve and are continuous with the pores on the exterior. The bars between the sockets can scarcely be considered denticulae, as they do not rise above the level of the floor of the valve. The cardinal process is short, moderately stout, scarcely projecting beyond the hinge line; it is completely bifid, each half appears to be slightly grooved on the extremity. In front of the process and continuous with it at the base is a low median ridge, rounded at the summit and extending anteriorly to the middle of the valve. From the base of each half of the process a ridge diverges and curves outward and forward a short way, forming the posterior border of the muscle area. Muscle scars are a short distance anterior to the process; the two middle adductors are elongate, parallel to the median ridge, and even encroach on it; a little posterior and lateral to them are two posterior adductors, which are crescentic and partially enclosed by the lateral ridge. There is also a small curved ridge between the anterior and posterior adductors.

The remainder of the interior of the brachial valve, except for a narrow belt adjacent to the lateral and anterior margins, is generally, sometimes completely, marked by small rounded papillae; these have no definite arrangement other than a slight suggestion of concentric lines. In one gerontic specimen some of the papillae are elongated, appear to be hollow, and might be considered to be endospines similar to those in *Chonetes*.

Pholidostrophia was based on *Strophodonta nacrea* Hall from the Hamilton of New

York. Hall later said that *Strophodonta lepida* Hall of the Cedar Valley beds of Iowa was the same, and he reduced *S. lepida* to synonymy. Schuchert (1897) discovered that the type specimen of *Chonetes? iowensis* Owen preserved in the National Museum was a *Pholidostrophia* and the same as *S. lepida* Hall. He therefore made *Strophodonta nacrea* a synonym of *P. iowensis*. After studying numerous examples of *Strophodonta nacrea* from six localities, we have concluded that species is sufficiently different from *Pholidostrophia iowensis* to warrant separate specific distinction.

In his revision of the genera of the Strophodontidae, Caster (1939) placed *Pholidostrophia* in the subfamily Strophonellinae. It differs from all other genera of that subfamily in not having a resupinate shell. The present writer agrees with Caster's suggestion that the *Pholidostrophia* group of brachiopods may deserve subfamily if not family ranking.

In this study of *Pholidostrophia* resemblances to some members of the *Chonetidae* have been suggested. *Pholidostrophia* resembles members of *Chonetes* in size and shape and in the development of palintropes in both valves. In the wall of the pedicle palintrope of *Pholidostrophia* are tubes extending toward the exterior, in some instances reaching it, in a manner somewhat homologous with the tubes below the spines of *Chonetes*. Internally the muscle area of the pedicle valve is similar, and there is a median ridge. The regions beyond the scars are likewise papillose. The brachial interiors also display similarities in the two genera. The muscle region has three ridges: a median and a longer one, and a curved one on either side between the adductor scars. The development of elongated papillae into endospines is seen in both genera.

There are also some striking differences between the two genera. In *Pholidostrophia* the denticulae are strongly developed along the hinge line, teeth and sockets are not present, there are no spines along the posterior border of the palintrope, deltidia are indistinguishable from the palintrope, and the shells are not costate. It may be suggested here that *Pholidostrophia* is related to the noncostate chonetids on the one hand and to the strophodontids on the other.

PHOLIDOSTROPHIA IOWENSIS (Owen)
Plate 7, figures 44–49

Chonetes? iowensis OWEN, *1852*, Geol. Survey Wisconsin, Iowa and Minnesota, p. 548, pl. 3A, fig. 7.
Strophodonta lepida HALL, *1850*, Geology Iowa, vol. 1, pt. 2, p. 493, pl. 3, fig. 3.
Strophodonta nacrea HALL, *1867*, New York Geol. Survey Paleontology, vol 4, p. 105.
Pholidostrophia iowensis, SCHUCHERT, *1897*, U. S. Geol. Survey Bull. 87, p. 308.
Pholidostrophia iowensis, GRABAU and SHIMER, *1909*, North Am. Index Fossils, pp. 219–220.
Pholidostrophia iowensis, CLELAND, *1911*, Wisconsin Geol. Survey Bull. 21, p. 90, pl. 18, figs. 5–7.
Pholidostrophia iowensis, BRANSON, *1923*, Devonian of Missouri, pp. 82–83, pl. 11, fig. 9.

Shell below medium size, moderately concavo-convex, wider than long, widest at the midlength, transversely subrectangular, with nearly straight lateral margins and rounded anterolateral margins. Two medium-sized hypotypes measured 9.6 and 11.6 mm. in length, 11.6 and 14.3 mm. in width, and 2.7 and 3 mm. in thickness. A larger specimen from the *independensis* zone measured 14.1 mm. in length, 17.3 mm. in width, and 5.7 mm. in thickness.

Pedicle valve moderately convex, highest at the midpoint, whence the surface slopes with even curvature to the margins, arched from beak to front and more strongly so in the umbonal region, slightly depressed at the cardinal angles; beak small, scarcely projecting; palintrope flat, transversely striated, about 1 mm. in height, and decreasing in height gradually toward the extremities, unmarked by deltidial plate or opening, and lying in the plane of the valve. Internally the muscle area is broadly flabellate, centrally emarginate in front, distinctly depressed below the surface at the posterolateral margins, but merging gradually at the front with the remainder of the valve beyond the midlength. The diductor scars are large, oval in outline, and separated by a broad, low ridge, which extends posteriorly to the apex and carries four small, ovate, paired scars. Around the muscle area and on the anterior portion of the median ridge are a number of scattered conical papillae.

Brachial valve gently concave, flat in the central and posterior portions, and curved upward near the lateral and front margins; area linear. Internally in the gently convex

central portion of the valve immediately in front of the midlength is a pair of elongate oval adductor scars. Posterior and lateral to them is a pair which are curved, smaller, and less elongate. Separating the scars is a low rounded median ridge, which extends forward beyond the central point. The surface of the remainder of the valve is broken by numerous scattered depressed conical papillae. There is also the faintest suggestion of three short divergent ridges in front of the muscle area.

The surface of the valve is devoid of costae but is marked by a few strong lamellose growth lines and many finer concentric striae. The shell substance is whitish, porcellanous in well-preserved specimens, and chalky in others. No puncta were observed in the specimens at hand.

Owen (1852) illustrated and described briefly a small brachiopod, which he called *Chonetes? iowensis*. Hall (1858) described one as *Strophodonta lepida*. Hall had previously described a New York form as *Strophomena* (*Strophodonta*) *nacrea* in 1857. In 1867 Hall decided that *Strophodonta lepida* was a synonym of his *Strophodonta nacrea*. Schuchert in 1897 noted that Owen's type specimen of *Chonetes? iowensis* is the same as *Strophodonta lepida* and *Strophodonta nacrea* of Hall. He, therefore, placed these names in synonymy with *Chonetes? iowensis*, which, taking the new generic name of Hall and Clarke, became *Pholidostrophia iowaensis* (Owen). The original spelling, *iowensis*, of the specific name is used in preference to *iowaensis*.

A number of specimens from the *profunda* and *independensis* zones differ from the hypotypes obtained from the type locality and horizon in being smaller, flatter in the umbonal region, and more convex anterior to the midlength. In other respects, however, they are similar. Apparently specimens of this smaller, more convex type were in Hall's hands when he described *Strophodonta lepida*. Further study may show other differences, and this name may be used to designate this variety, which occurs nearly 40 feet below the horizon of *Pholidostrophia iowensis*.

I am inclined to regard *Strophodonta nacrea* Hall as a separate species from *Pholidostrophia iowensis* (Owen), since it differs in being more convex at the midlength or anterior to it and in having the cardinal angles more extended. Internally, also, *Strophodonta nacrea* has the three divergent ridges in front of the muscle area more prominently developed.

Occurrence.—Cedar Valley limestone, in the *Cranaena iowensis* zone is the horizon from which Owen obtained his specimens, but similar forms also occur in the *profunda* and *independensis* zones. Specimens have been obtained at Iowa City, Robert's Ferry, Linder's Boathouse, Midriver, Solon, and elsewhere in Johnson county; Vinton, Brandon, Independence, Linn Junction, Fayette, in Iowa; Wisconsin; Missouri.

Types.—The holotype is no. 17942 in the National Museum at Washington. Hypotypes are S.U.I. 6-346 and 6-336; M.A.S. 24, 29, 36, and 273.

Family CHONETIDAE Hall and Clarke
Genus CHONETES Fischer de Waldheim

Shells concavo-convex, usually wider than long, with or without a faint median sinus in the pedicle valve and a faint fold on the brachial. A palintrope is present in both valves, and deltidium and chilidium are distinct. Spines are present along the posterior border of the pedicle valve, and the exterior of the shell is radially costate.

Internally in the pedicle valve the hinge teeth are moderately developed. The muscle scars are faintly impressed on the floor, and the visceral disc may or may not be distinctly defined. The median septum is high in the delthyrial cavity and a little anterior. Remainder of the valve beyond the muscle scars is marked by numerous small papillae. In the brachial valve the process is short, bifid, and posteriorly grooved. The sockets are short and generally parallel to the hinge line. The visceral disc is more or less distinct and may be marked by enlarged papillae, which when broken appear to be hollow. It is marked by a median ridge, which may or may not be elevated into a septum, and by a flanking ridge posteriorly on either side. Radiating ridges bearing papillae may be present over much of the interior or visible only on the belt beyond the visceral disc.

This brief summary of the characteristics of *Chonetes* results from a study of several Pennsylvanian species of the genus that are

exceptionally well preserved and display the internal features of both valves.

Chonetes is represented in the Cedar Valley by four species, which fall into three groups. In one the shell is moderately long in proportion to the width, and the pedicle valve is strongly arched and lacks a sinus. The second group has transverse shells, a sinus in the pedicle valve, and a fold in the brachial. The third is plicate externally instead of costate when the size of the plicae is compared with the size of the shell.

These Devonian species differ in some respects from typical Pennsylvanian species. The muscle scars are usually much less distinctly impressed on the interior. The brachial valve, internally, is usually more completely marked by papillose radiating ridges. A median septum is not distinctly developed in the brachial valve, nor is there a smaller ridge on either side of it posteriorly. The papillae are also not strongly developed enough to be endospines.

CHONETES SCHUCHERTI Cleland
Plate 7, figures 24–28

Chonetes schucherti CLELAND, *1911*, Wisconsin Geol. Survey Bull. 21, p. 91, pl. 18, figs. 11–13.

Shell small, gently concavo-convex, wider than long, with the hinge line equal to or less than the greatest width, semielliptical in outline, with nearly rectangular cardinal angles and rounded anterolateral margins. Dimensions of two hypotypes are: length, 8.3 and 5.6 mm.; width, 10.8 and 7.8 mm.

Pedicle valve most convex near the middle, the surface sloping thence to the margins with moderate rapidity and flattening toward the cardinal angles; umbo prominent, beak small. Palintrope flat, of moderate height, decreasing gradually and evenly in height to the extremities, slightly inclined to the plane of the valve, and divided by a convex deltidium, which is strongly concave at the base. Spine bases small, inconspicuous, numbering 3 or 4.

Interior of the pedicle valve divided into two areas, the central visceral disc occupying the central and larger portion of the valve and the narrow peripheral area or "trail." The visceral disc is deep and sharply delimited along the posterolateral borders but is chiefly distinguished anteriorly and laterally by the abrupt downward flexure of the surface. It is divided by a low, broadly rounded median ridge, which extends across the disc. Posteriorly, however, it is superseded in the delthyrial cavity by a high, thin erect median septum, which ends abruptly about 1 mm. in front of the hinge teeth. Muscle areas not distinctly impressed on the interior, flabelliform and confined to the posterior half of the visceral disc. The remaining portion of the interior is more or less distinctly marked by radiating rows of small papillae. The "trail" is narrow and marked by the inward bending of the valve beneath the external costae; these ridges are minutely papillose. The hinge-teeth are short, stout and unsupported below.

Brachial valve shallow, deepest in the central portion, the surface sloping abruptly from the cardinal margin, then gently to the middle, and thence gradually upward to the anterior and lateral margins. Palintrope more than half as high as that of the pedicle valve and making an obtuse angle with it; chilidium well developed, convex, and meeting the deltidium a short way beyond the hinge line so as to close the pedicle opening completely. Internally the muscle scars are shallow triangular depressions, distinctly defined at the sides and about 1 mm. long. The cardinal process is subrectangular in shape, bifid, sharply limited on either side by a deep curved dental socket, and directed posteriorly and outward a short distance beyond the hinge line. Beyond the muscle area the rest of the valve is marked by numerous small narrow ridges radiating from the muscle scars and strongly papillated throughout their extent; the two radiating ridges on either side of the midline are slightly larger. They and the ridge between may be homologous with those developed in Pennsylvanian species.

Exterior of both valves marked by fairly coarse angular costae, which extend from the beak to the margins where, on the average, 30 may be counted. On the pedicle valve, increase is by division, but in some specimens a few costae may be intercalated between the others. On the brachial valve increase is by division.

Many of the specimens at hand occur embedded in blocks of limestone, and rarely are any secured free from the matrix. They vary in color as to locality, but in general the

shells have a purplish tinge. A small variety occurs abundantly in some localities and averages about 3 mm. less in width. Further collecting may show it worthy of separate designation. The same variation is found in the Milwaukee area.

This species in the faunal lists published in reports of the Iowa Geological Survey commonly has been referred to *Chonetes scitulus* Hall of the Hamilton beds of New York and elsewhere. *Chonetes schucherti* is smaller than that species and has fewer costae, 30 as compared to 60. Specimens from Iowa were compared with examples of *Chonetes schucherti* from the type locality at Milwaukee, Wisconsin, and were found to be the same.

Occurrence.—Cedar Valley limestone in the *bellula* zone just below the "coral reef" at Linder's Boathouse, Rapid Creek, and Aicher's Quarry in Johnson county, Moscow, Buffalo, and Linwood, in Iowa; Milwaukee, Wisconsin.

Types.—Hypotypes: M.A.S. 254, 1325, 1368; C.H.B. 6618 and 6442.

CHONETES BUCHANANENSIS
Stainbrook, n. sp.
Plate 7, figures 19–23

Shell gently concavo-convex, semielliptical in outline, with the anterolateral margins rounded, the front margin nearly straight, and the cardinal angles extended, considerably wider than long, with the greatest width along the hinge line. Measurements of the holotype and of a paratype are: length, 6.9 and 6.7 mm.; width, 11.6 and 9.7 mm.; convexity of the pedicle valve 1.8 and 1.5 mm.

Pedicle valve gently convex, evenly arched from the beak to the front margin, highest at the midpoint, the surface gently flattened near the cardinal angles; depressed centrally by a broad, extremely shallow sinus extending from the umbo to the front and indistinctly defined at the sides. Along the cardinal margin on either side of the indistinct beak are on the average four or five laterally directed spine bases. Palintrope low, flat, situated in the plane of the valve, high beneath the beak, gradually and evenly decreasing in height to the extremities; beneath the surface, canals leading outward to the spines are visible. Delthyrium closed at the beak by a convex deltidium but open at the base and disclosing there the cardinal process of the opposite valve. Internally the hinge teeth are small, flat, anteriorly extended in the plane of the valve, broadest toward the center of the valve, and becoming narrower toward the cardinal extremities. The muscle area is large, cordiform, extended anteriorly beyond the midlength, and divided posteriorly by a short, stout median septum, which is high and erect in the delthyrial cavity but descends abruptly beyond and gradually merges toward the front with the floor of the valve.

Brachial valve shallowly concave, flattened in the umbonal region, beyond which the surface curves upward evenly and gradually to the margins, elevated a little in the areas enclosed by the cardinal angles. Palintrope low, less than half as high as that of the pedicle valve.

Internally the surface of the valve is marked by small narrow radiating ridges, which are minutely papillated along their summits, more strongly so anteriorly. These internal ridges correspond to the external costae. The cardinal process is small, apparently bifid, but the forks are so closely approximated as to appear as one. Each apophysis is grooved on the posterior surface. Muscle scars are faint and scarcely distinguishable. In front of each dental socket there is a slight depression, which diverges from the middle of the valve. Apparently there is no median septum or ridge as in Pennsylvanian species; two of the radiating ridges on either side are slightly enlarged.

Surface of both valves broken by rather stout angular radiating costae, numbering from 30 to 36 on average specimens and about two occupying the space of 1 mm. on the umbo. The intercostal spaces are as wide as the costae except along the lateral and front margins. Increase is by intercalation on the pedicle valve and by division on the brachial, each process accomplished several times. Crossing the costae are minute concentric striae and a few stronger lines of increment.

Chonetes buchananensis is wider than *Chonetes schucherti* Cleland in proportion to length, is not as convex, has a shallow sinus on the pedicle valve, and has stouter costae,

which are farther apart. The same set of characters with smaller size will separate this form from *Chonetes scitulus* Hall.

Occurrence.—Cedar Valley limestone in the *waterlooensis* zone at Littleton and Brandon, Iowa.

Types.—Holotype: S.U.I. 6-349A; paratypes S.U.I. 6-349 and M.A.S. 31.

CHONETES BELLARUGOSUS
Stainbrook, n. sp.
Plate 7, figures 29–31

Shell very small, moderately concavo-convex, wider than long, with the hinge line equalling the greatest width, subrectangular to semielliptical in outline, with subparallel lateral margins and rounded anterolateral margins. Dimensions of the holotype and of two paratypes are: length, 4.8, 4.8, and 6.2 mm.; width, 6.3, 6.4, and 7.7 mm.

Pedicle valve is moderately and regularly convex, the surface attaining the highest point in the center of the valve and sloping thence evenly to the lateral and front margins and more rapidly to the hinge line, gently depressed by a narrow, shallow, rather indistinct median sinus extending from beak to front. Umbonal region moderately convex; beak small. Palintrope low and decreasing rapidly in height toward the cardinal angles. Exterior marked by moderately large rounded plications, which increase by division, accomplished once, and number about 18 on average specimens. The plications are crossed by numerous minute, rounded, somewhat irregular, concentric wrinkles, which give a characteristic appearance to the shell. One, two, or three outwardly directed spines may be present on the cardinal margin of the pedicle valve. Interior unknown.

Brachial valve shallowly concave, deepest in the central portion and elevated toward the cardinal angles. The plications are similar to those of the opposite valve, being similarly marked, but differ in increasing by intercalation. Interior unknown.

The minuteness of the shell, the large plications, and the regular concentric wrinkles distinguish this brachiopod from any other known to me.

Occurrence.—Cedar Valley limestone where the form is characteristic of the basal portion of the *profunda* zone and top of the *independensis* zone at Linn Junction, Vinton, Independence, Waverly, Davenport, and Janesville, Iowa.

Types.—Holotype is S.U.I. 6-369A; paratypes are: M.A.S. 7, 47, 191 and 256. No. 79436 of the National Museum is a specimen of this species.

CHONETES CALVINI Stainbrook, n. sp.
Plate 7, figures 11–13, 16–18

Chonetes cancellatus CALVIN, *1894*, Iowa Geol. Survey, vol. 4, p. 167. (Nomen nudum.)

Shell of medium size, concavo-convex, transversely subelliptical in shape, with the cardinal extremities extended and auriculate, nearly twice as wide as long, with the hinge line equalling the greatest width. Measurements of the holotype and of a paratype are: length, 16.8 and 14.8 mm.; width, 27.7, and 23.8 mm. (incomplete); convexity of the pedicle valve, 6.7, and 6 mm.

Pedicle valve moderately convex, highest near the middle, depressed mesially by a broad, shallow, indistinctly defined sinus extending from beak to front; toward the cardinal extremities the surface slopes downward away from the borders of the sinus and then upward, so that the lateral margins are depressed a little below the front margin; beak small and slightly projecting; cardinal margin sharply defined and bearing four or five small spines on either side of the beak. Palintrope low, gradually decreasing in height toward the extremities; the narrow triangular delthyrium is closed by a convex deltidium. Internally the hinge teeth are short, stout and supported by the greatly thickened edges of the palintrope. The muscle area is heart-shaped, extends beyond the midlength, and is distinctly defined posteriorly from the rest of the valve but less distinctly toward the front. A high median septum originating in the delthyrial cavity decreases gradually in height toward the front and becomes obsolete near the midlength. Interior beyond the scars marked by minute papillae, which tend to be in radiating lines near the margins of the valve.

The brachial valve is deeply concave and is depressed more on either side of the midline. A broad mesial fold, scarcely perceptible, extends from the beak to the anterior margin. A gently concave and slightly elevated area is enclosed by each cardinal

angle. Palintrope low but nearly half as high as that of the opposite valve. Interior known only from a poorly preserved example; it does not show the radial papillose ridges to any extent.

The surface of both valves is marked by numerous fine broadly rounded costae, which increase by division. They are crossed by a large number of minute concentric rounded close-set ridges scarcely visible to the unaided eye. Several lamellose lines of increment may interrupt the continuity of the costae.

This is the form that Calvin designated by the name *Chonetes cancellatus* but no illustration or description was given. The name also has been employed in faunal lists by Norton and Savage. This species is similar in some respects to *Chonetes manitobensis* Whiteaves but is larger and possesses more extended angles.

Occurrence.—Cedar Valley limestone in *independensis* zone at Independence, Linn Junction, and Vinton, Iowa.

Types.—Holotype, S.U.I. 6-339A; paratypes S.U.I. 6-339, 6-419, and M.A.S. 9, 33, 229, and 259.

Family PRODUCTIDAE Gray
Subfamily PRODUCTELLINAE Schuchert and Le Vene

There are three types of productids in the Devonian of Iowa, but only two are represented in the Cedar Valley formation.

Genus PRODUCTELLA Hall

Productella HALL, *1867*, New York State Cab. Nat. History Ann. Rept. 20, p. 250.
Productella, HALL, and CLARKE, *1892*, New York Geol. Survey Paleontology, vol. 8, pt. 1, p. 328, pl. 17, figs. 1–2.
Productella, KING, *1930*, Texas Univ. Bull. 3042, p. 65.
Productella, WELLER, *1914*, Mississippian Brachiopoda, p. 97.

The genus was proposed by Hall and the first species following the generic diagnosis is *Productella subaculeata* Murchison. This species Hall and Clarke (1897) state had been identified by De Verneuil as occurring in Devonian strata near Charlestown, Ind., which beds they state to be Hamilton in age. Hall (1867) illustrated an example from Indiana to represent the species and genus. Schuchert (1897) placed this Indiana species under *Productella spinulicosta* Hall, and *Productella subaculeata* (Murchison) is not recognized as occurring in North America. As no specimens of the genotype are at hand recourse must be made to the description of that species by De Koninck, quoted by Hall (1867, p. 154) and to the illustration of the species by Walcott (1884).

Shell small to medium in size, strongly concavo-convex, and with the hinge line equalling or less than the breadth.

Pedicle valve gibbous, regularly arched from beak to front and lacking a sinus. Surface marked by many faint growth striae and numerous spine bases, which are generally circular or slightly elongate, irregularly distributed, but more closely aggregated on the angles and on either side of the beak; angles eared. Area low, divided by a triangular delthyrium. Beak short, umbo gibbous.

Brachial valve concave, arched as the opposite valve, marked by concentric wrinkles, which are more strongly defined upon the ears and upon the sides, and by "rounded fossettes" irregularly distributed and corresponding to the spine bases of the opposite valve. No spines are mentioned as present on the brachial exterior. Length, 16 mm.; slightly wider, about 19 mm.; convexity 10.3 mm. Number of spines ranges from 25–50. As no specimens of *Productella subaculeata* (Murchison) are at hand we have no way of ascertaining definitely the further distinguishing characteristics of the genus. However, *Productella belanskii*, n. sp., described and illustrated below agrees with *P. subaculeata* and has the same generic characteristics above enumerated. A number of well-preserved specimens of this latter species are at hand and yield further important details in addition to those given by Hall. These are summed up in the following diagnosis of *Productella*.

Shells small to medium-sized, strongly concavo-convex, eared, with long straight hinge line, which may be equal to or less than the greatest width.

Pedicle valve highly arcuate, with prominent umbo and small beak produced beyond the hinge line; palintrope low, decreasing gradually in height to the extremities, divided into two parts by a broad low del-

thyrium, which in all specimens at hand lacks a deltidium. Exterior nonplicate, although the elongate spine bases may give the surface a pseudoplicate appearance; the areas between the spine bases are quite smooth; growth rugae numerous, concentric, somewhat irregular, continuous over the umbo and discontinuous anteriorly, more strongly expressed in the areas on either side of the umbo near the hinge line. Spine bases numerous, not definitely arranged, hollow, often elongate posteriorly, sometimes circular, crowded on the ears near the hinge line. Spines when present are long, slender, cylindrical, hollow, laterally directed on the sides of the valve and anteriorly on the front and middle portions. Internally the hinge teeth are small but well developed and are not supported by dental plates beneath, although there is a slight thickening below the edges of the delthyrium. Muscle area large, flabelliform, striated, more or less indistinctly impressed on the floor, not bordered by distinct ridges. Remainder of the valve marked by numerous minute obscure papillae and by small depressions beneath the spine bases. The visceral chamber is not distinctly set off from the remainder of the valve.

Brachial valve strongly concave, deepest centrally, and with elevated areas enclosed by the angles. Beak small; umbo concave. Palintrope very low, less than half as high as that of the opposite valve and about at right angles to it. Surface not plicate but marked by numerous concentric, somewhat irregular rugae, which are more numerous and nearly continuous on the posterior portion of the valve but more strongly developed on the angles. Small subcircular depressions are scattered over the surface and apparently correspond to the spine bases of the opposite valve. Internally the cardinal process is small, projects downward and backward beyond the hinge line; it is bifid, each part being grooved on the posterior extremity. On either side of the process is a short dental socket. In front of the process is a depression, from whose anterior border rises a slight thin median septum extending shortly beyond the midlength and attaining a height of 0.5 mm. The muscle area is but slightly impressed on the surface and scarcely distinguishable. A slight groove originates on each side near the posterior end of the median septum, diverges laterally for some distance before swinging inwards in a broad curve toward the anterior end of the septum. The surface is marked by a few slight discontinuous irregular concentric wrinkles and numerous scattered minute papillae.

Hall and Clarke (1897) state that the delthyrium is apparently covered in both valves. It is open in all specimens available to us, and the above diagnosis may be enlarged to encompass those species with deltidia.

PRODUCTELLA SUBALATA Hall

Productus subalatus HALL, *1857*, Tenth Rept. New York State Cab. Nat. History Ann. Rept. 10, p. 174.
Productus subalatus, HALL, *1858* Iowa Geol. Survey vol. 1, pt. 2, p. 500, pl. 3, fig. 10.
Productella subalata, HALL, *1867*, New York Geol. Survey Paleontology, vol. 4, p. 165, pl. 23, fig. 49.
Productella subalata, HALL, *1883*, New York State Geologist Ann. Rept. 2, pl. 48, fig. 16.
Productella subalata, HALL and CLARKE, *1892*, New York Geol. Survey Paleontology, vol. 8, pt. 1, pl. 17, fig. 16.
Productella subalata, SCHUCHERT, *1897*, U. S. Geol. Survey Bull. 87, p. 318.

Shell semielliptical, with the cardinal extremities alate; ventral valve gibbous in the middle, depressed in front, abruptly incurved, the umbo projecting above the hinge line; the cardinal margin marked by more or less distinct folds or wrinkles, becoming obsolete on the middle of the shell, which is crossed by irregular or undulating concentric striae. In some individuals, indistinct longitudinal striae are visible. Surface ornamented by numerous strong rounded tubular spines, the bases of which remain irregularly distributed. Some well-preserved specimens show a distinct row of spines near the cardinal margin, while those nearest the beak are small, and actually upon the edge of the shells as in *Chonetes*. HALL, 1857.

This species is reported by Hall to occur in calcareous shales of the age of the Hamilton group of New York at Rock Island, Illinois. The types are preserved in the American Museum of Natural History. One additional specimen has been collected but is not available for study at this time.

Occurrence.—Cedar Valley limestone in the *waterlooensis* zone at Buffalo, Iowa, in beds containing *Cyrtina curvilineata* White, *Schizophoria lata* Stainbrook, and others.

PRODUCTELLA BELANSKII Stainbrook, n. sp.
Plate 7, figures 1–7

Shell of medium size, strongly concavo-convex, wider than long, with the greatest width anterior to the hinge line, subquadrate in outline, with the lateral margins rounded and meeting the front margin in a broad curve, and with the cardinal angles slightly rounded and a little auriculate. Dimensions of the holotype and of two paratypes are: length, 23.8, 20 and 23.7 mm.; width, 24.6, 24, and 23.3 mm.; convexity of the pedicle valve, 11.1, 10.1, and 11.7 mm.

Pedicle valve strongly convex, arched from beak to front and posteriorly recurved beneath the beak, highest at the midpoint, whence the surface curves rapidly and evenly to the anterolateral and front margins and more strongly on either side of the umbo to the posterolateral margins, flattened at the cardinal angles; umbo strongly developed and extended beyond the hinge line; beak small and incurving. Palintrope low, curved, highest at the beak, decreasing rapidly in height toward the extremities, and interrupted centrally by a triangular opening, through which the cardinal process is visible; a deltidium may have been present, but none is preserved in any of the specimens at hand. The posterior part of the valve is marked by numerous small concentric rugae, which are continuous over the umbonal region but obsolete anteriorly and centrally. Spine bases large, numerous, more abundant on the growth wrinkles near the cardinal angles and farther apart elsewhere. They are situated at the anterior extremities of low, short, indistinct, oblong, narrow, radiating ridges, which give a pseudocostate appearance to the shell. A more or less regular row of larger spines extends from beak to front along the median line. Spines, where preserved, are smooth, erect, slender, hollow, and several millimeters long. Internally the valve is indistinctly divided into a deep visceral disc and a narrow trail. The disc is bordered posteriorly and laterally by a faint ridge, which becomes obsolete anteriorly. The muscle area is not strongly impressed on the floor of the valve; in the posterior part are two short oblate muscle scars separated posteriorly by a low ridge and anteriorly by a short narrow depression; beyond these toward the front are the very large diductor scars, which are indistinctly separated from the remainder of the valve. On either side of the pedicle opening is a short laterally divergent hinge tooth resting on the hinge plate, which is distinctly thickened below. The interior of the valve beyond the muscle area is marked by numerous small granules and shallow irregular scattered circular depressions beneath the spines.

Brachial valve deeply to shallowly concave, but in no specimen equal to the convexity of the opposite valve, depressed in the umbonal region, elevated and flattened in the areas enclosed by the cardinal angles; area linear. Surface broken by faint, more or less irregular concentric rugae, which are more prominent near the cardinal angles and nearly obsolete in the central portion of the valve. There are also small circular pits corresponding in position to the spines of the opposite valve. There is no evidence of spines. Internally the cardinal process is bifid, with the apophyses short, divergent, slender, longitudinally grooved at the extremities and projecting a little posteriorly. A short way in front of the cardinal process arises a low median septum, which gradually increases in height, then becomes lower, and disappears shortly beyond the mid-length. At the posterior end of the septum and on either side a short narrow furrow extends laterally and anteriorly for several millimeters and divides equally the areas between the median septum and the hinge line. The remainder of the valve is broken by a series of minute irregular concentric wrinkles, on and between which are scattered numerous small granules, oblong in shape, radiating from the beak, and having the appearance of incipient spines.

Productella belanskii differs from *Productella subalata* Hall is not being as wide in proportion to length and in having more numerous and more strongly developed spines. This form differs from *Productella harberti* in being longer in proportion to width, in having larger and more numerous spines, and in having the wrinkles of growth less strongly developed on the posterior portions of the shell.

Occurrence.—Cedar Valley limestone, in the *independensis* zone at Independence,

Waverly, Vinton, Linn Junction, Davenport, and Solon, Iowa.

Types.—The holotype is S.U.I. 6-342; paratypes are S.U.I. 6-341, and M.A.S. 32, 190, 225, 274, and 1312.

PRODUCTELLA HARBERTI Stainbrook, n. sp.
Plate 7, figures 8–10, 14, 15

Shell of medium size but large in comparison with other members of the genus, subquadrate in outline, with rounded anterolateral margins, strongly concavo-convex, wider than long in most specimens, with the hinge line less than the greatest width, and with the cardinal angles a little extended and slightly auriculate or rounded due to wear. Measurements of the holotype and of a paratype are: length, 22 and 21 mm.; width, 25 and 23 mm.; convexity of the pedicle valve, 11 and 10 mm.

Pedicle valve strongly convex, highly arched along the midline from beak to front, with the curvature greatest posterior to the midlength, most convex at the midpoint, whence the surface slopes with moderate rapidity to the anterior and lateral margins and more rapidly to the hinge line. Umbonal region prominent and projecting a short way beyond the cardinal margin; beak small and a little extended; palintrope linear. Surface marked by numerous persistent concentric rugae, which are crowded on the umbo, farther apart anteriorly, and obsolete a short way beyond the midlength. Spine bases small, few in number, irregularly spaced, and distant from each other.

Brachial valve deeply concave, but the concavity does not equal the convexity of the other valve. Internally the cardinal process is bifid, with the two halves weak and closely approximated; in front of them is a slight depression, which quickly becomes obsolete anteriorly, being superseded by a small, low, mesial septum extending to the center of the valve; the floor of the valve is made irregular by strong concentric continuous rugae. Muscle scars scarcely visible.

This species is as large as *Productella belanskii* but can be distinguished readily from it by the scarcity of spines, by the less protuberant umbo, and by the greater development of the concentric growth wrinkles. It also differs from *Productella subalata* Hall in having more numerous growth rugae and in having the length and breadth more nearly equal. A characteristic feature possessed by specimens of this species and shared by other brachiopods in the same zone is the distinct reddish color of the shells.

Named in honor of Mr. A. N. Harbert of Shellsburg, Iowa, under whose guidance and by whose aid the specimens were collected.

Occurrence.—Cedar Valley limestone in the *bellula* zone of the Rapid member, at Shellsburg, Brandon and Littleton, Iowa.

Types.—Holotype is S.U.I. 6-343A; paratypes are S.U.I. 6-342 and M.A.S. 275.

PRODUCTELLA LINNENSIS
Stainbrook, n. sp.
Plate 7, figures 38–43

Shell small, deeply concavo-convex, subovate in outline, with slightly auriculate angles, longer than wide, and broadest along the hinge line. Measurements of the holotype and of a paratype are: length from umbonal region to front margin, 10 and 11.7 mm.; width, 9.3 and 9 mm.; convexity of the pedicle valve, 6.5 and 6.6 mm.

Pedicle valve long, gibbous, greatly arched from beak to front, with the curvature greatest at the back, highest at the midpoint, the surface sloping abruptly to the front and more abruptly to the lateral and posterolateral margins; umbonal region prominent, arcuate, and extending beyond the hinge line; beak strongly incurving. Externally the spine bases are few in number, scattered irregularly, and posteriorly elongated. Growth striae fine and crowded. Rugae present on angles.

Brachial valve deeply concave, flattened in the posterior portion, deepest at the midpoint, and with the surface curving thence strongly to the anterior and lateral margins. Marked externally by small rounded concentric rugae, which are more prominent toward the angles. Numerous small pitlike depressions are scattered in the bottoms of the depressions between the rugae and appear to correspond to the spine bases on the opposite valve.

The small size, length, narrowness, and gibbosity of the pedicle valve readily separate this form from any other in the Iowa Devonian. The specimens at hand are pre-

served in a hard limestone and are difficult to free from the matrix. The description above applies to exfoliated valves.

The small size and the length of the highly arcuate pedicle valve separate this species from *Productella spinulicosta* Hall.

Occurrence.—Cedar Valley limestone in the *profunda* zone at Linn Junction and Brandon, Iowa. A form reported from the Mineola of Missouri by Branson, as *Productella spinulicosta* may possibly be referable to the above species.

Types.—Holotype, S.U.I. 6-345A; paratypes S.U.I. 6-345.

Genus DEVONOPRODUCTUS Stainbrook, n. gen.

The second generic type of small productiform shells in the Iowa Devonian is that seen in the species *Productella walcotti* Fenton and Fenton (*Productus dissimilis* Hall). No example occurs in the Cedar Valley limestone as far as is known, but it is present in the shale below. The characters are summed up in the following diagnosis:

Shell small to medium in size, productiform, auriculate at the angles, strongly concavo-convex, with straight hinge line, which may be less than the greatest width; proportion of breadth to length and height variable among individuals of the same species; ephebic specimens are usually longer than wide.

Pedicle valve strongly arched from beak to front, more strongly so posteriorly, strongly arched transversely in the central part, and expanding toward the front. Cardinal angles depressed and slightly extended, at least in ephebic examples. Umbo prominent, high, extended beyond the hinge line, worn in most examples but apparently not attached. Palintrope extremely low, reduced, nearly linear; in specimens with closely appressed valves is often scarcely visible when examined with the unaided eye. It is divided into two parts by a low delthyrium, which is usually concealed by the beak. There is no evidence of a deltidium; the space being occupied by the cardinal process of the opposite valve. The exterior is marked by numerous small to minute costae, which increase by division several times from beak to front. Spine bases usually subcircular, sometimes elongate, sparse, irregularly scattered over the surface, situated on one or more costae, which pass through and not around the bases. Spines when present are erect, strong, hollow, cylindrical, and more or less perpendicular to the surface of the valve. They may have been several millimeters in length. Along the hingeline are four or five spine bases, which project upward and backward in a manner somewhat reminiscent of *Chonetes*.

Internally a deep visceral chamber is distinctly set off from the smaller remaining portion of the valve. It is semioval in shape and broadest anteriorly. The posterior and lateral borders are formed by a ridge, which diverges from the base of the hinge tooth on either side and swings outwardly in a broad curve toward the front, where it becomes indistinct. The posterior portion of the ridge may be projecting and shelflike. The muscle scars are weakly impressed on floor and are usually indistinct. As far as can be discerned they occupy a large part of the visceral disc and are marked by a few radial striae. The remainder of the valve, which may be designated as the trail, is narrow and marked by many minute rounded crowded papillae. The hinge teeth are greatly reduced, microscopic, being merely projections of the angle formed by the hingeline and a side of the delthyrium. In most specimens they are not evident, only two individuals show them unmistakably. Small dimples are present along the hingeline beneath the spines; they do not appear elsewhere on the valve interior.

The brachial valve is shallowly concave, deepest centrally, and in an area which broadens laterally and anteriorly from the beak. Umbo concave; beak small, rounded, slightly elevated. Surface marked by numerous regularly spaced angular concentric wrinkles of growth, which are strongly laminose when well preserved. Between the laminae are numerous fine concentric striae. Close inspection also demonstrates the presence of faint radiating costae, which are interrupted by the growth laminae. The latter are homologous with the rugae of the pedicle valve and give the characteristic appearance to the valve. The shell substance where worn appears to be strongly pustulose. No palintrope is distinguishable.

In the interior the dental sockets are

nearly obsolete and are hardly distinguishable as such, being merely niches between the apophyses of the process and the posterior edge of the valve. Interior distinguishable as a large visceral disc and a narrow trail. The disc is subovate in outline, broadest anteriorly and bordered posteriorly on each side by a narrow ridge, which originates at the base of the cardinal process and curves anteriorly to disappear near the middle of the valve. Bisecting the visceral area is a narrow, thin median septum, which originates a short distance anterior to the process and extends a little beyond the midpoint. At this place it attains its maximum height. The anterior portion of the visceral disc in some examples is limited by narrow grooves originating at the anterior end of the septum and diverging laterally and posteriorly in broad curves to the region in front of the process, where they disappear. The muscle areas are faint and often imperceptible. The scars are elongate, flabellate, and do not reach the midpoint. Surface of the visceral disc generally smooth except toward the front, where it may be slightly marked by radial striae. That portion of the valve exterior to the visceral disc is marked, especially along the front, by numerous crowded pointed projections. They are spinose in appearance, apparently hollow where broken, pointed, and may be termed endospines.

Devonoproductus resembles *Productella* in shape, in the presence of a pedicle palintrope, a delthyrium, teeth, spinose pedicle and nonspinose brachial valves, in the possession of a median septum in the brachial valve, and in having rugae on the pedicle valve. It differs from *Productella* in having the exterior of the valves costate, the brachial valve strongly lamellose, and in not showing dimples on the brachial valve opposite the spines of the pedicle excepting along the hingeline. *Devonoproductus* lacks a palintrope in the brachial valve, has the teeth and sockets greatly reduced, has the visceral disc of each valve distinctly set off from the trail, and has a diaphragm in the pedicle valve in the form of shelves along the posterior borders of the visceral area. *Devonoproductus* also has endospines on the brachial interior on the trail.

This genus may be the radicle from which later genera of productids have been developed. It could easily lead to *Productus* by the development of reticulate umbonal regions, by establishment of continuous rugae, and by the loss of teeth and sockets and palintrope. It could also lead with few changes to *Linoproductus* by the reduction of the brachial growth lamella, palintrope and spines.

The genotype is *Productus dissimilis* Hall, 1858 (not *Productus dissimilis* de Koninck 1846). This homonym is replaced by *Productella walcotti* Fenton and Fenton (1924). The shell is common in the Cerro Gordo

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EXPLANATION OF PLATE 6

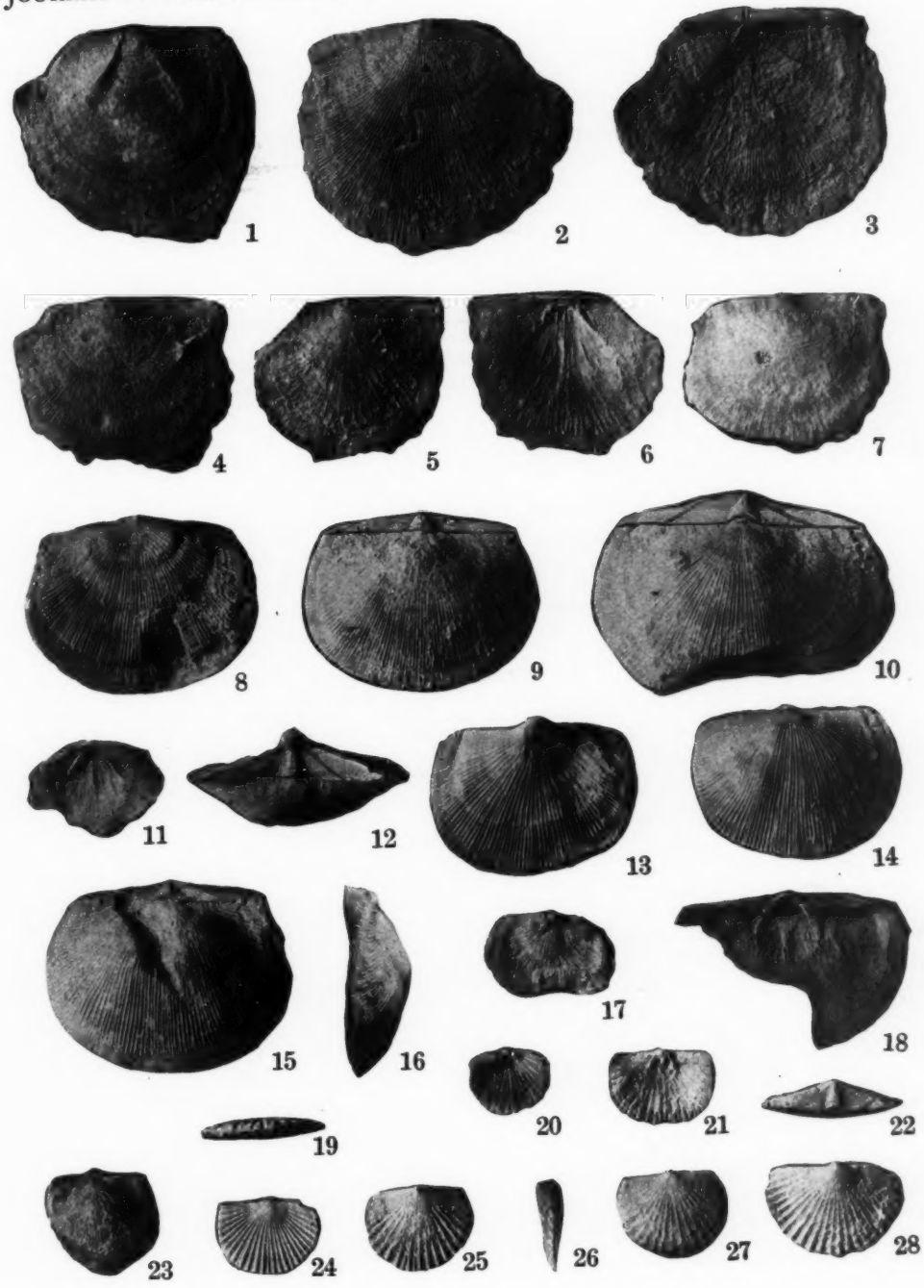
FIGS. *1—Leptostrophia perplana* (Conrad). Pedicle view of a hypotype from the Hamilton of New York, for comparison with Cedar Valley species. (p. 39)

2–4, 11—Leptostrophia occidentalis Stainbrook, n. sp. *2, 3*, Pedicle and brachial views of the holotype (S.U.I. 6-333A). *4*, Pedicle view of a paratype (M.A.S. 10). *11*, Internal view of a small incomplete pedicle valve, paratype (S.U.I. 6-333). All from Littleton, Iowa. (p. 40)

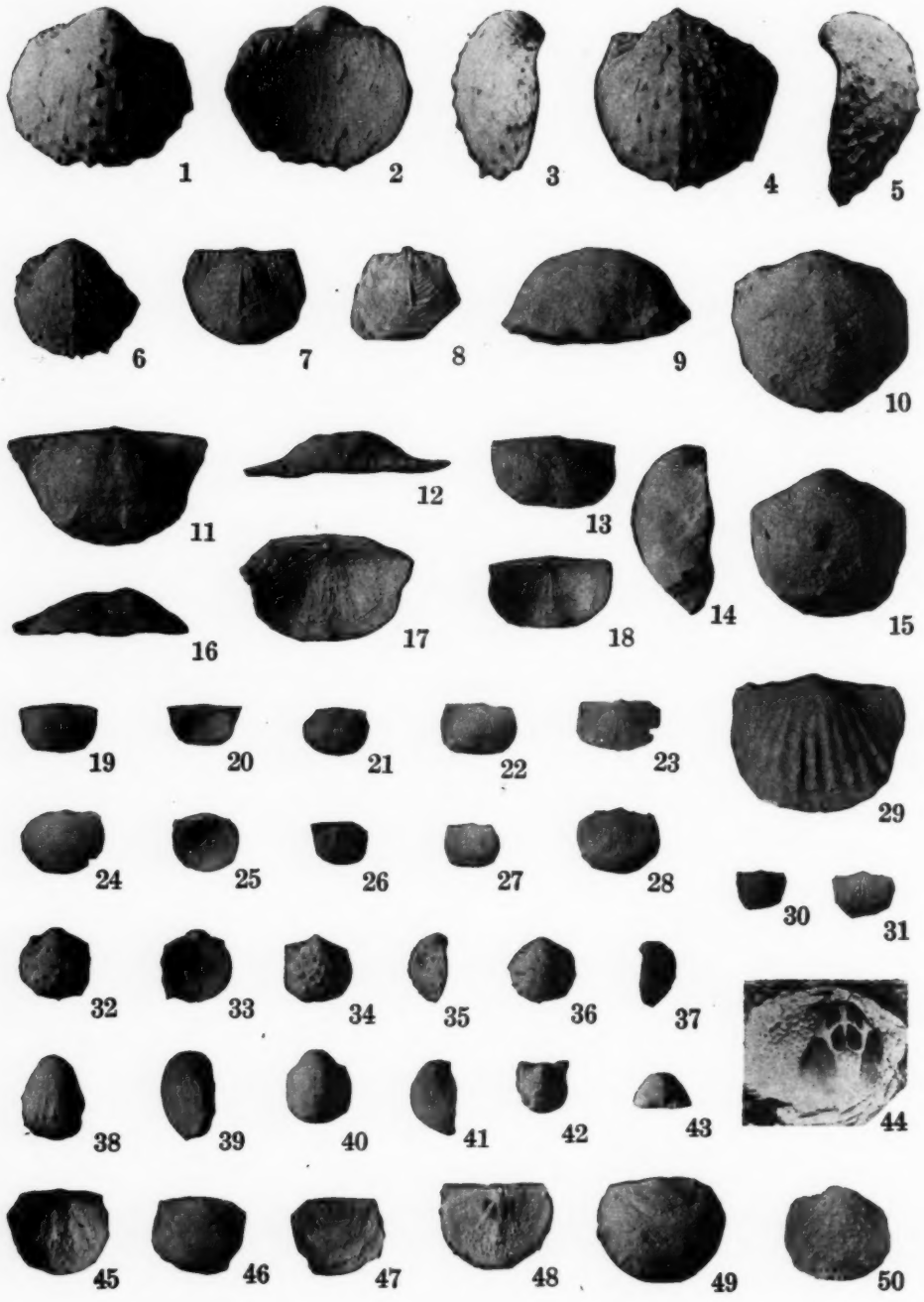
5–7—Leptostrophia fragilis (Hall). *5–6*, External and internal views of a pedicle valve, hypotype (S.U.I. 6-331). *7*, Pedicle view of a hypotype (S.U.I. 6-331). Both from Rock Island, Ill. (p. 40)

8–10, 12–18, 23—Schuchertella iowensis Stainbrook, n. sp. *8–9*, Pedicle and brachial views of the holotype (S.U.I. 6-323A). *10*, Brachial view of a paratype (M.A.S. 10). *12–14*, Posterior, pedicle and brachial views of a paratype (S.U.I. 6-323). *15, 16*, Brachial and lateral views of a paratype (M.A.S. 3). *18*, Internal view of a pedicle valve, a paratype (M.A.S. 15A). All from the *bellula* zone at Brandon, Iowa. *17, 23*, Brachial and pedicle views, respectively, of two specimens from the *waterlooensis* zone at Brandon, Iowa. (p. 42)

19–22, 24–28—Schuchertella? orthoplicata Stainbrook, n. sp. *19, 25–27*, Anterior, pedicle, lateral and brachial views of a paratype (M.A.S. 34). *20*, Internal view of a brachial valve, paratype (M.A.S. 34B). *21*, Internal view of a brachial valve (S.U.I. 6-327). *22, 28*, Posterior and pedicle views of a large paratype (M.A.S. 24). *24*, Brachial view of the holotype (S.U.I) 6-328). All from Linn Junction, Iowa. (p. 43)



Stainbrook, Devonian Brachiopoda



Stainbrook, Devonian Brachiopoda

member of the Lime Creek stage of the Upper Devonian of Iowa. A representative also is present in the Independence shale.

Genus STROPHALOSIA King, 1884

The third type of small productiod shell in the Iowa Devonian is one similar to *Strophalosia* of authors. It differs from either of the genera described above and from *Leptalosia* Dunbar and Condra (1932) in having spines on the brachial valve. There are at hand examples of species from the Independence shale, Lime Creek shale, and from the Snyder Creek formation of Missouri. The following diagnosis is made from a study of specimens of all these species:

Shell small to medium size, productiform, strongly concavo-convex, with straight hinge line, which may be equal to or less than the greatest width, suborbicular in outline.

Pedicle valve of variable convexity, more strongly arched in the umbonal region, showing no evidence of a sinus. Palintrope of moderate height, flat, considerably higher on the average than that of *Productella*, and decreasing in height to the extremities. Delthyrium closed by a deltidium. In one species there is no sign of a deltidium distinct from the palintrope. In another it is indicated by a slight indentation at the base. In a third the deltidium is slightly convex. Beak usually short and may show a scar of attachment or appear as though sliced away. This scar may vary in size in the same species, being so small in one specimen that the beak projects and in another may be one or two millimeters in diameter. Umbo variable,

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EXPLANATION OF PLATE 7

FIGS. *1–7—Productella belanskii* Stainbrook, n. sp. *1, 3*, Pedicle, brachial and lateral views of a paratype (M.A.S. 23), Waverly, Iowa. *4, 5*, Pedicle and lateral views of the holotype (S.U.I. 6-342), Independence, Iowa. *6*, Pedicle view of a paratype (M.A.S. 32). *7*, Internal view of a brachial valve, paratype (M.A.S. 190), Independence, Iowa. (p. 53)

8–10, 14, 15—Productella harberti Stainbrook, n. sp. *8*, Internal view of a brachial valve, paratype (S.U.I. 6-348). *9, 10*, Posterior and pedicle views of the holotype (S.U.I. 6-348A). *14, 15*, Lateral and pedicle views of a paratype (S.U.I. 6–348). All from Shellsburg, Iowa. (p. 54)

11–13, 16–18—Chonetes calvini Stainbrook, n. sp. *11, 12*, Pedicle and posterior views of the holotype (S.U.I. 6-339A). *13, 18*, External and internal views of a pedicle valve, paratype (M.A.S. 33). *16, 17*, Anterior and brachial views of a paratype (S.U.I. 6–420). All from Independence, Iowa. (p. 50)

19–23—Chonetes buchananensis Stainbrook, n. sp. *19*, Pedicle view of a paratype. *20*, Internal view of a pedicle valve, the holotype (S.U.I. 6-349A). *21, 22*, Pedicle views of two paratypes. *23*, Internal view of a brachial valve, a paratype. Paratypes figured are (M.A.S. 31). All types are from Littleton, Iowa. (p. 49)

24–28—Chonetes schucherti Cleland. *24, 25*, External and internal views of two hypotypes (M.A.S. 1374). *26*, Pedicle view of a small specimen (M.A.S. 254). All from vicinity of Iowa City. *27, 28*, Pedicle views of a large and a small hypotype (M.A.S. 1299) from type locality at Milwaukee, Wis. (p. 48)

29–31—Chonetes bellarugosus Stainbrook, n. sp. *29*, Pedicle view, ×4, of a paratype (M.A.S. 256). *30, 31*, Pedicle views of two paratypes (M.A.S. 256 and 7). Independence, Iowa. (p. 50)

32–37—Strophalosia? littletonensis Stainbrook, n. sp. *32, 33*, Pedicle and brachial views of the holotype (S.U.I. 6-347A). *34—37*, Pedicle and lateral views of two paratypes (S.U.I. 6-347). All from Littleton, Iowa. (p. 58)

38–43—Productella linnensis Stainbrook, n. sp. *38, 39*, Pedicle and lateral views of the holotype (S.U.I. 6-345A). *40, 41*, Pedicle and lateral views of a paratype. *42, 43*, Exterior and posterior views of the external mold of a brachial valve, a paratype. The paratypes are (S.U.I. 6-345). All from Linn Junction, Iowa. (p. 54)

44–49—Pholidostrophia iowensis (Owen). *44*, Internal view of a pedicle valve, ×2, (S.U.I. 6-334). *45*, Internal view of a pedicle valve (M.A.S. 29). *46, 47*, Pedicle and brachial views of an incomplete hypotype (M.A.S. 29). *48*, Internal view of a brachial valve (M.A.S. 273). All from Johnson county, Iowa. *49*, Pedicle view of a large hypotype (M.A.S. 24), Independence, Iowa. (p. 46)

50—Strophalosia rockfordensis Hall and Clark. Pedicle view of a hypotype (M.A.S. 1359), Lime Creek beds near Rockford, Iowa. (p. 58)

usually not strongly developed as compared with that of *Productella*. Angles auriculate and rarely extended. Surface of the valve not plicate or costate; marked by concentric rugae, more or less continous and more strongly developed on the ears, and by fine irregular growth striae. Spines abundant, long, hollow, slender, pointed, and oblique, regularly scattered over the surface of the valve and if present mostly recumbent on it. Bases of spines elongated a little posteriorly and may give a falsely costate appearance to the surface. No complete pedicle interior is at hand, but broken valves yield a few details. There is a slight development of a shelf on the posterolateral border of the visceral disc. Hinge teeth not observed but presumably present because of the well-developed palintrope. Muscle areas not observed. In the Independence shale species the inner surface below each spine is marked by a small circular depression, which appears to communicate with the hollow interior of each spine instead of being closed by shell deposition as in *Productella*. This feature was observed only in one specimen and may not be general to the genus.

Brachial valve shallowly concave, deepest near the center or back of it, elevated near the angles. Surface marked concentrically by fine striae and by somewhat irregular and discontinuous rugae, which are slightly stronger in front of the hinge-line. Palintrope flat, low, decreasing rapidly in height to the extremities, half as high as the opposite palintrope or more and making an obtuse angle with it. Chilidium narrow and slightly convex. Beak faint, gently convex. Spines long, slender, tapering, abundant, scattered evenly over the surface, oblique, directed outwardly toward the lateral and anterior margins, recumbent; bases small and on the crests of the rugae. Where the surface is worn the spine bases may be difficult to detect.

Internally the cardinal process is bifid, and each portion is longitudinally grooved on the posterior surface. A short, low, narrow median septum extends anteriorly from its origin a short distance in front of the process. Muscle scars faintly impressed on the surface. Remainder of the interior marked by small papillae, which in some species may become short endospines.

Strophalosia has spines strongly developed on both valves, and its species can thus be easily separated from those of *Leptalosia*, which lack spines on the brachial exterior. Members of the latter genus also are usually attached by the major portion of the pedicle exterior. *Productella truncata* Hall, mentioned by Dunbar and Condra as a species of *Leptalosia*, has spines on the brachial valve and therefore should be excluded from that genus as defined by them.

Etheridgina Oehlert has a lamellose brachial valve and lacks a palintrope.

Girty (1905) expressed his opinion that the genotype of *Strophalosia* has the characters of that group of shells placed under the generic term *Aulosteges*, and that this latter name is a synonym. If this is true, and I have no means of ascertaining, the group of shells that have been generally placed in *Strophalosia* and which are quite different as suggested by Girty and R. E. King (1930), should have a distinct generic designation.

We would propose the name *Eostrophalosia* for those productiform brachiopods whose distinguishing characteristics have been given above in the diagnosis of *Strophalosia*, with *Strophalosia rockfordensis* Hall and Clarke as the genotype, and *Strophalosia callawayensis* (Swallow) as an example. An undescribed species from the Independence shale belongs here and possibly *Strophalosia? littletonensis* Stainbrook, n. sp.

Subfamily STROPHALOSIINAE Schuchert
Genus STROPHALOSIA King
STROPHALOSIA? LITTLETONENSIS
Stainbrook, n. sp.
Plate 7, figures 32–37

Shell small, about as wide as long, subquadrate in outline, slightly auriculate at the angles, with rounded anterolateral margins and the hinge line less than the greatest width. Dimensions of the holotype and of a paratype are: length, 8.8 and 10 mm.; width, 9.2 and 10 mm.; convexity of the pedicle valve, 4.5 and 5 mm.

Pedicle valve strongly convex, highest at the midpoint, whence the surface curves rapidly to the anterior and lateral margins, strongly over the umbo to the beak but more rapidly toward the cardinal extremities, slightly flattened toward the cardinal

angles; umbonal region prominent and projecting beyond the hinge line; beak small, slightly incurving and bearing at the apex a small circular to oval cicatrix. Palintrope low, nearly at right angles to the plane of the valve, divided by a delthyrium, which may or may not be covered by a deltidium. Surface of the pedicle valve marked by numerous prominent and distinct spine bases arranged in irregularly alternating rows radiating from the beak and elongated posteriorly so as to suggest short costae. The spaces between the spines are crossed by numerous minute concentric growth striae and by abundant fine discontinuous radiating lines. The spines, of which only broken remnants usually remain, are long, hollow, slender and recumbent.

Brachial valve moderately concave, flattened in the umbonal region, and curving strongly upward near the lateral and front margins; palintrope low and coincident with the plane of the valve. Interior unknown.

The surface of the brachial valve is marked by numerous fine concentric striae and by irregularly scattered shallow subcircular to oblong pits. No evidence of spines has been detected on the brachial exterior, but it is possible that they may have been present. The shells are peculiarly preserved, being mostly silicified and chalky white. Apparently also the specimens were cleaned rather vigorously. This apparent lack of spines casts doubt on the assignment of this species to *Strophalosia*. On the other hand, in the possession of abundant long, slender recumbent spines on the pedicle valve, in the presence of a callosity on the pedicle beak, and in the appearance of the shells, it resembles closely other members of the genus. It might possibly be placed in *Leptalosia* but is not attached by the greater portion of the pedicle valve. The small attachment scar probably indicates that attachment was only a brief phase in its neanic history.

Again the species seems to be nearly related to *Productella*. Apparently it is intermediate between *Productella* and *Strophalosia*. During the Devonian, these productiform brachiopods seem to have been diverging and may not yet have become distinctly differentiated. It is quite possible that some species may not be clearly referable to the various divergent genera.

Occurrence.—Cedar Valley limestone in the *waterlooensis* zone, in the beds commonly called in Survey reports by Calvin, "the Yellow shales," at Littleton and Brandon, Iowa.

Types.—The holotype is S.U.I. 6-342; paratypes S.U.I. 6-342 and M.A.S. 433.

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ACILA PRINCEPS, A NEW UPPER CRETACEOUS PELECYPOD FROM CALIFORNIA

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ABSTRACT—The new species occurs in a sand lentil in the Moreno formation in sec. 12, T. 12 S., R. 10 E., M.D.M., Merced County, California. It is related to *Acila* (*Truncacila*) *demessa* Finlay from the Chico formation of Butte County, California, but differs chiefly in its larger size and coarser ornamentation. Also illustrated are the following Upper Cretaceous specimens: a topotype of *A. demessa; Acila* (*Truncacila*) sp. D from near Martinez; two specimens of *Acila* (*Truncacila*) sp. E from the Marca shale member of the Moreno formation; two specimens of *A. demessa* from the Pleasants sandstone; one specimen of *A. demessa* from the upper Holz shale; and *Acila* (*Truncacila*) sp. F from the Cretaceous of Baja California.

INTRODUCTION

DETAILED geologic mapping on the west side of the San Joaquin Valley, California, by Max B. Payne resulted in the discovery of a large number of fossils in strata of late Cretaceous age. Among the specimens sent to Stanford University in 1941 is a new species of nuculid pelecypod, here described as *Acila* (*Truncacila*) *princeps*. Acknowledgment is due the Chief Geologist, Richfield Oil Corporation, and Messrs. Mason Hill and Payne of that company, for the generous donation of specimens, stratigraphic data, helpful suggestions, and for permission to publish this new record.

W. P. Popenoe, California Institute of Technology, identified some of the pelecypods associated with the new species and lent many specimens of *Acila demessa* from several localities. G. Dallas Hanna and Leo G. Hertlein, California Academy of Sciences, and Bruce L. Clark, University of California, also provided comparative material. Gary Ellis, R. A. C. Brown, and Ivan F. Wilson aided the writer in 1941 in the collection of specimens of *Acila princeps* at the type locality. Allan P. Bennison supplied data regarding fossils collected by him. Joseph A. Cushman, Sharon, Mass., and Helen Jeanne Plummer, Austin, Texas, sent specimens of foraminiferal species for comparison with those in the local California section. At Stanford University, Lois T. Martin identified critical foraminiferal faunules; Konrad B. Krauskopf prepared a report on the matrix; Siemon Wm. Muller and A. Myra Keen criticized an early draft of the typescript; Mrs. Carl F. Janish and Alexander Tihonravov aided in the preparation of the illustrations; P. W. Reinhart, Donald C. Birch, and Elizabeth A. Watson collected well-allocated specimens from the Marca member of the Moreno formation and from Cretaceous beds in Contra Costa County; C. F. Green, who has made a detailed geologic map of the Charleston School quadrangle, generously permitted the use of much stratigraphic information; and finally, the Research Committee supplied funds for the investigation. It is a privilege to acknowledge all of this assistance and cooperation.

GEOLOGIC OCCURRENCE

The new species is from Stanford University locality 2372, in a sandstone lentil in the Moreno formation, as shown on the accompanying geologic sketch map, figure 1.

Stratigraphically above the Moreno formation in the Charleston School quadrangle are beds of Paleocene age overlain by Eocene strata. These formations are not differentiated on the sketch map.

Immediately below the Paleocene strata is a brown shale, approximately 330 feet in thickness, which is thought by Payne to be the correlative of the upper part of the Tierra Loma shale member of the type Moreno formation. Payne believes that a disconformity here separates the Cretaceous shale and the Tertiary sandstone. At locality M-261 (NE ¼ sec. 13, T. 12 S., R. 10 E.) near the base of the Cretaceous shale member, C. F. Green collected a foraminiferal

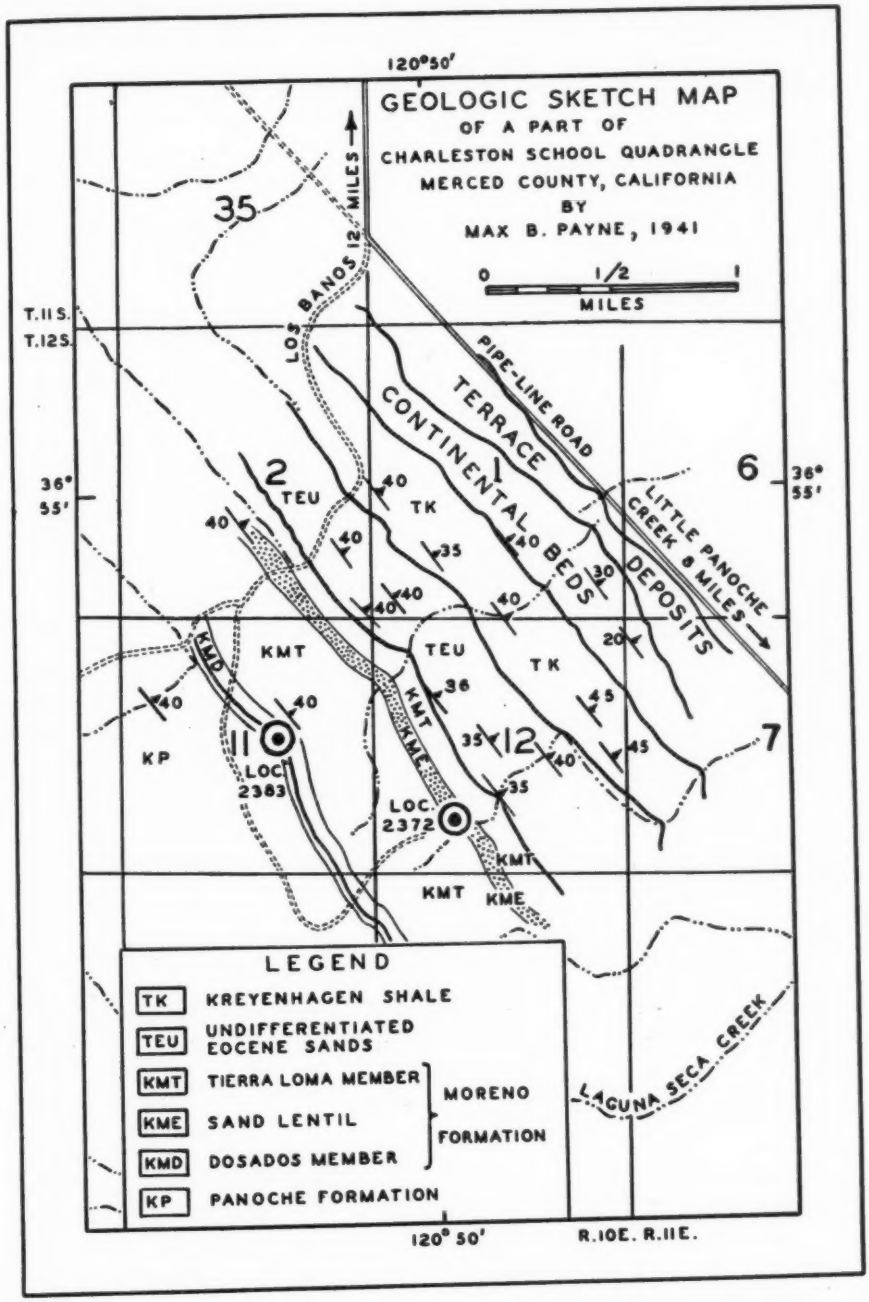


FIG. 1.—Geologic sketch map of a part of Charleston School quadrangle, Merced County, Calif. Type locality of *Acila princeps* is No. 2372.

faunule with abundant specimens of *Bulimina prolixa* Cushman and Parker, *Siphogenerinoides whitei* Church, and other species, which he has recorded in his report (1942).

Conformably below the upper shale member is a sandstone lentil totalling 200± feet in thickness at this locality. It is in this member at locality 2372 that the new species of *Acila* was found. The matrix of the specimens is described by Konrad B. Krauskopf (report dated June 14, 1941) as follows:

> The rock has so much calcite cement that it might be described as a sandy limestone almost as well as a calcareous sandstone. The quartz and feldspar grains range up to 0.2 mm., and the mica flakes up to 1.0 mm. There is little material in the finer silt grades, the majority of grains being over 0.02 mm. The grains are extremely angular; some of the quartzes show reentrant curves, and some are so elongated as to resemble glass shards.
>
> The most abundant mineral is quartz, which aggregates about 50 percent of the light minerals. Feldspar (orthoclase 25 percent, plagioclase 25 percent) and a little muscovite make up the remaining light minerals. All varieties of feldspar are relatively fresh. Heavy minerals are abundant, their relative proportions being approximately as follows:

	Percent
Green hornblende	71
Colorless zircon	9
Ilmenite	9
Epidote and clinozoisite	5
Garnet	3
Sphene	2
Biotite	1
Blue tourmaline	>1
Andalusite	>1

> By way of a guess, I would suggest that the good sorting points to marine deposition, the freshness of the material suggests rapid deposition without a great deal of weathering, and the general mineral assemblage indicates a dominant metamorphic or basic igneous provenance.

The conformably subjacent lower Tierra Loma shale member consists of 1310± feet of brown shale. No diagnostic molluscan fossils have as yet been discovered from this member of the Moreno in this area.

Conformably underlying the thick brown shale member is a sequence of beds which has been differently correlated and named by several workers. Along a line of section through locality 2372, one finds a thickness of about 120 feet of alternating sandstone and shale below the lower Tierra Loma shale member. Where the outcrops are satisfactory, one can see that the upper 70–80 feet of the alternating sandstone and shale correspond lithologically to the Dosados member of the type Moreno formation, whereas the lower 40–50 feet consist chiefly of massive, fossiliferous, concretionary sandstone and conglomerate. It is this sandstone and conglomerate which Payne takes to be the uppermost member of the Panoche formation, as shown in figure 1. Green's treatment is somewhat different. He believes (oral communication) that because the strata are difficult to differentiate northwestwards along the strike it is more satisfactory to recognize only a single cartographic unit (about 550 feet thick) below the lower Tierra Loma shale member: a unit composed of the Dosados sandstone and shale, the upper member of the Panoche (as mapped by Payne), a subjacent shale member, and a lower massive sandstone. Some workers have placed the top of the Panoche formation still lower in the section. The disputed part of the column (that is, whether Moreno or Panoche) is more than 750 feet in thickness.

Among the Upper Cretaceous mollusks in the Panoche formation as mapped by Payne (fig. 1) at locality 2383 are the following: *Acila* (*Truncacila*) sp., *Cophocara* sp., *Glycymeris veatchii* (Gabb), *Hamites* cf. *ellipticus* Anderson, *Parallelodon* sp., and *Tenea inflata* (Gabb). At the nearby locality 2489 (1250 feet E., 2800 feet N. of SW cor. sec. 13, T. 12 S., R. 10 E.) on the north side of Laguna Seca Creek and only a few feet lower stratigraphically, *Acila* (*Truncacila demessa* Finlay occurs in some abundance, associated with other fossils listed by Green (1942). These molluscan fossils at localities 2383 and 2489 aid in defining the Panoche formation in the Charleston School quadrangle.

Further evidence bearing on the placement of the boundary between the Moreno and Panoche formations in this area is a faunule with *Globotruncana arca* (Cushman) found by Green at locality M-260 (2350 feet N., 300 feet E. of the SW corner sec. 13, T. 12 S., R. 10 E.). The foraminiferal shale at this locality is approximately 850 feet stratigraphically below the lower Tierra Loma shale member, as here mapped. Some geologists believe that the beds carrying these fossils should be allocated to the

Panoche formation, whereas others place them in the lower Moreno.

Whatever the interpretation of the uppermost limit of the Panoche formation, no geologist familiar with the stratigraphy of the district denies the fact that the sandstone member containing the new species of *Acila* is well above the top of that formation. Attention is further directed to the fact that *Acila princeps* at its type locality occurs 1440± feet stratigraphically above a sandstone carrying *Acila demessa*. It is significant that *Acila princeps* is a Moreno species and is geologicaly younger than *A. demessa*.

SYSTEMATIC PALEONTOLOGY

ACILA (TRUNCACILA) PRINCEPS Schenck, n. sp.

Plate 8, figures 1–4, 6–8

Type material.—Holotype no. 6960, figured paratypes nos. 6961, 6962. Stanford University Paleontological Type Collection.

Type locality and age.—Stanford University Locality No. 2372, Merced County, California, Charleston School quadrangle, 1200 feet north, 1650 feet east of the SW cor. sec. 12, T. 12 S., R. 10 E., M.D.B. & M. Sand lentil in the Moreno formation, Upper Cretaceous. The specimens are abundant.

Associated fossils.—*Glycymeris veatchii* (Gabb), *Parallelodon* (*Nanovavis*) cf. *brewerianus* (Gabb), *Tenea inflata* (Gabb), and other mollusks.

Description.—Adult shells large for subgenus, quadrangular, inflated; anterior dorsal margin straight to slightly convex; anterior end evenly rounded, with a relatively marked change of slope to meet the dorsal margin; ventral margin convex; posterior end straight, making a sharp angle with ventral margin; ratio of height to length varies from 69 to 82 percent, the median of 26 specimens falling at 79 percent; beaks small, strongly inturned, appressed; lunule and escutcheon not sharply set off; faint rostral sinus extending from near umbones to ventral margin slightly anterior to posterior end; surface of holotype sculptured by about 83 straplike radial ribs (pl. 8, fig. 8)—counted at midheight—which attain a maximum width of 0.5± mm., separated by interspaces up to 0.2 mm. wide but generally narrower; secondary bifurcation present on some specimens, anterior to primary bifurcation, which is anterior to center of shell; nature of ornamentation on escutcheonal area not determined; concentric lines form about six marked growth rings; area of obsolete radial ribbing present on holotype; interior smooth, nacreous; adductor muscle scars and simple pallial line impressed; central, median, and punctiform muscle scars (Schenck, 1934, p. 21) visible on some of the internal casts; marginal plications faint (pl. 8, fig. 3) owing to imperfect preservation of specimens; chrondrophore inclined anteriorly; about 22 anterior, 11 posterior teeth (pl. 8, fig. 2).

Dimensions.—The measurements of the better-preserved specimens of *Acila* (*Truncacila*) *princeps* in the original lot from locality 2372 are given in the table. The graph reproduced as text figure 2 is based upon measurements of these and additional specimens preserved as molds and casts.

COMPARISONS

Introduction.—A survey of the pelecypods of the genus *Acila* has been published by the writer in the several papers cited in the

Specimen	Length in mm.	Height in mm.	Thickness in mm. (2 valves)	Umbonal angle (degrees)	Angle of bifurcation (degrees)	Ratio of height to length (percent)
Holotype No. 6960	32.7	25.1	19.0	104	67	77
Paratype No. 6962	29.4	23.3	14.6	102	60	79
Paratype No. 6961	31.6	22.7				72
Paratype No. 6963	30.0	23.3	15.0	109	60	78

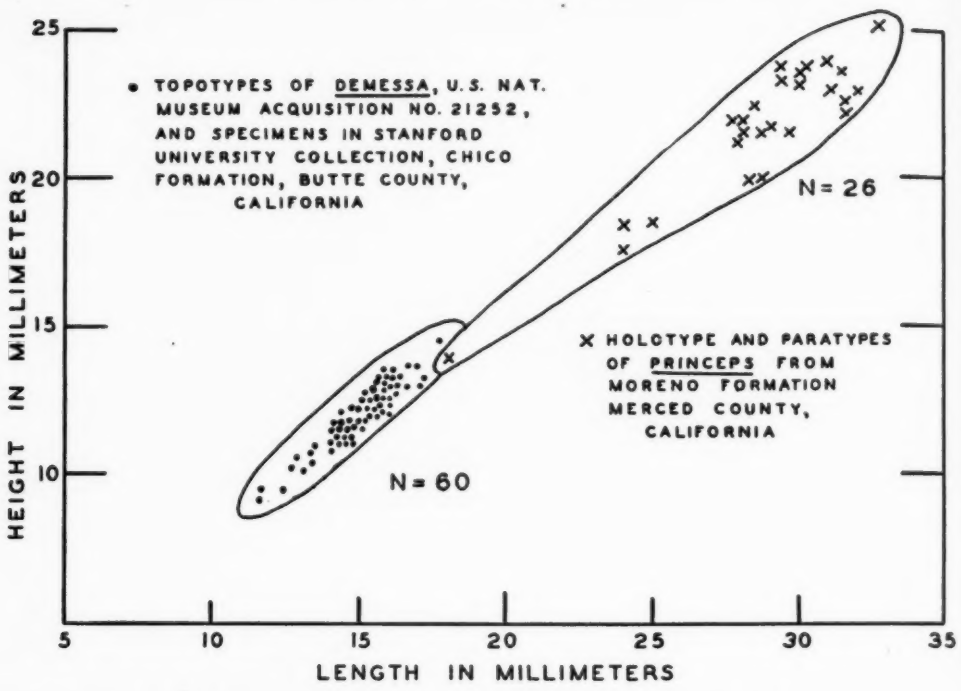


FIG. 2.—Height-length relations of *Acila princeps* compared with *Acila demessa*.

accompanying bibliography. Of the species there considered, only two Cretaceous species need to be discussed in comparison with the new species: *Acila* (*Truncacila*) *demessa* Finlay and *Acila* (*Truncacila*) *hokkaidoensis* (Nagao), 1932. The present discovery has necessitated a reexamination of a large number of Cretaceous specimens and a measurement of several hundred specimens, including Recent species. This study proved that some reliance may be placed upon dimensions for the separation of species.

Comparison with Acila demessa Finlay.—The new species, *Acila princeps*, is most nearly related to *Acila demessa* Finlay, a representative topotype of which is shown on plate 8, figure 5. Dimensions of topotypes are given in text figure 2; on the same graph are the dimensions of *princeps*. Measurements of more than one hundred additional specimens from Butte County, California, support the belief that the true *demessa* does not exceed a length of 20 mm.

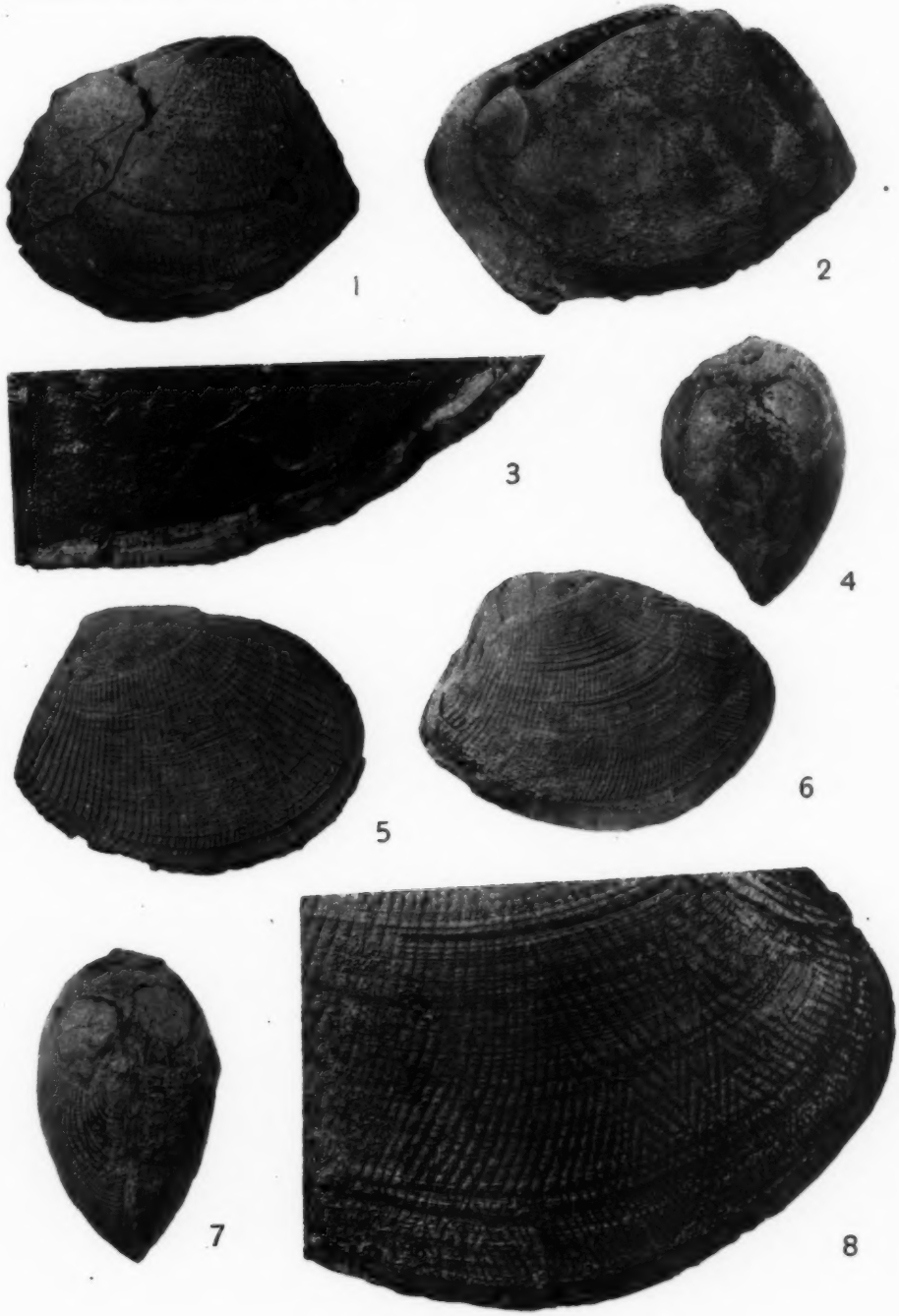
Representative examples of *A. demessa* from Orange County, California, are illustrated on plate 9, figures 1, 3, and 7. The specimen shown in figure 1 from the upper Holz shale is 14 mm. long and 11.2 mm.

EXPLANATION OF PLATE 8

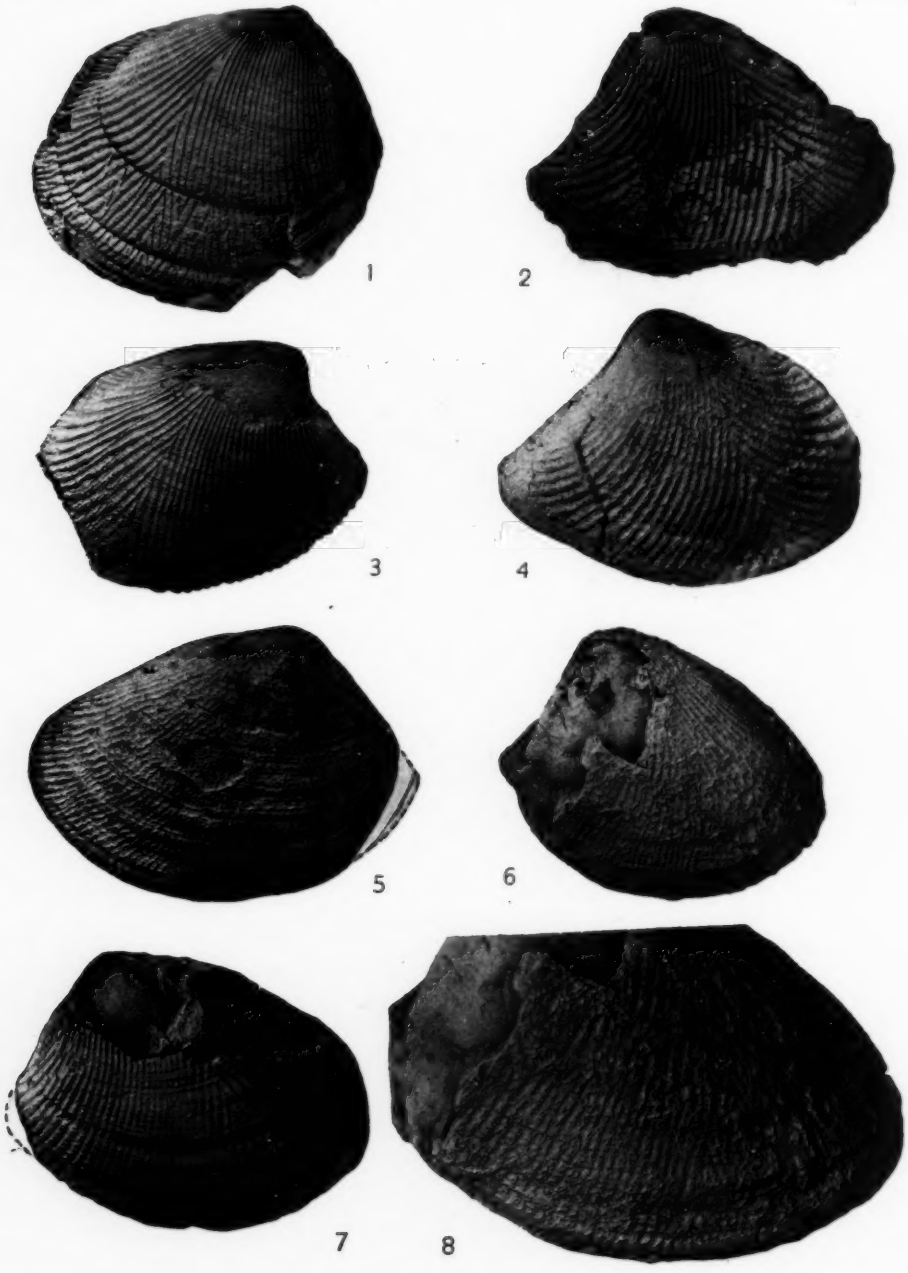
All specimens in Stanford University Paleontological Type Collection

FIGS. *1–4, 6–8—Acila* (*Truncacila*) *princeps* Schenck, n. sp. Sand lentil, Moreno formation (Upper Cretaceous), Merced County, California; L.S.J.U. loc. 2372, sec. 12, T. 12 S., R. 10 E., M.D.B.&M. *1*, Left valve, ×1.5; *3*, inner ventral margin, ×4; paratype 6962. *2*, Left valve, ×1.9; paratype 6961. *4*, Posterior view, ×1.3, *6*, right valve, ×1.3, *7*, dorsal view, ×1.3, *8*, anterior ventral portion, ×2.6; holotype 6960. (p. 63)

5—Acila (*Truncacila*) *demessa* Finlay. Chico formation, (Upper Cretaceous), L.S.J.U. loc. 361, near Pentz, Butte County, California. Right valve, ×3; hypotype 6959. This specimen is 15.5 mm. long, hence slightly less than one-half the size of the shell shown in figure 6. (p. 64)



Schenck, Upper Cretaceous Acilas



Schenck, Upper Cretaceous Acilas

high. As it was tilted when photographed in order to accentuate the details of the ribbing, the characteristic profile of the species cannot be judged from this figure. The Pleasants sandstone specimen shown in figure 7 measures 15.2 mm. in length, 12.3 mm. in height; this figure was designed to illustrate the nature of the ribbing on the posterior part of the shell; the exact profile of this valve is indeterminate owing to the matrix. Another Pleasants sandstone specimen, figure 3, is 13.5 mm. long, 10.6 mm. high.

The sculpturing of the two species is similar in proportions, but the ribs are wider in *A. princeps*. On the new species there are about 1.6 to 1.8 radial ribs per millimeter, in contrast to 2.2 to 2.4 ribs per millimeter on *A. demessa*. No distinct area of obsolete radial ribbing has been noted on topotypes of *A. demessa*, whereas this feature is present on the holotype of *A. princeps*.

In general, the umbonal angle of *A. demessa* appears to be greater than in *A. princeps*, the median of the former being 110°. The median of the ratio of height to length in *A. demessa is* 80 percent, whereas in *A. princeps* (N = 26) the median falls in the 79 percent class interval.

Comparison with Acila (Truncacila) sp. D. —On plate 9, fig. 5, is figured a specimen (type no. 7368, Stanford Univ. Paleont. Type Coll.) from the "Chico" formation exposed along the Santa Fe railroad near Martinez, Contra Costa County, California, at locality 2180 (75 mm. west, 20 mm. south of intersection of Lat. 38°00′ and Long. 122°05′, on the map of the Concord quadrangle). A description of the section through this locality is contained in a report by Watson (1941). According to current views on correlation based on foraminiferal faunules, the sandstone with this specimen is not only older than the Moreno formation but is also older than the lowest known occurrence of *Acila demessa*.

Acila (Truncacila) sp. D is about 21 mm. long, 14.6 mm. in height, thus falling into the general size category of *A. princeps*, but the largest radial rib is about 350 microns wide, in contrast to the coarser ornamentation of *A. princeps*. In sculpturing but not in proportions, therefore, *Acila* sp. D resembles *A. demessa*.

Comparison with Acila (Truncacila) sp. E. —On plate 9, figure 4, is illustrated a specimen (type no. 7369, Stanford Univ. Paleont. Type Coll.) from the Moreno formation in the NE corner of the SE¼ sec. 23, T. 16 S., R. 12 E., M.D.M., Fresno County, California, collector Donald C. Birch. This single specimen is a mold in a white-weathering limestone concretion in brown shale. This is the same species as that which the writer (1936-b, p. 50) has called "*Acila (Truncacila)* cf. *demessa*," as based on hypotype no.

EXPLANATION OF PLATE 9

Specimens illustrated in Figs. *1, 3, 7* at California Institute of Technology; others in Stanford University Paleontological Type Collection.

FIGS. *1, 3, 7—Acila (Truncacila) demessa* Finlay. Upper Cretaceous, Corona Quad., Santa Ana Mts., Orange Co., California. *1*, Left valve, ×3.5, from Upper Holz shale, C. I. T. loc. 1059, ¼ mi. above mouth of Harding Canyon. *3*, Left valve, ×3, from Pleasants sandstone, C. I. T. loc. 975, 300 feet NW of middle of S line of sec. 29, T. 5 S., R. 7 W., S.B.M. *7*, Right valve, ×3, Pleasants sandstone, C. I. T. loc. 974, middle of S line of sec. 29, T. 5 S., R. 7 W., S.B.M. Hypotypes, C. I. T. nos. 4650–4652. (p. 64)

2, 4—Acila (Truncacila) sp. E. Marca shale member, Moreno formation (Upper Cretaceous) *2*, Right valve, from L.S.J.U. loc. 2574, 1000 feet. NE of center of sec. 17, T. 19 S., R. 15 E., M. D. B. & M., Fresno County, California; a crushed specimen, ×2.2, details of profile uncertain; hypotype 5906, *4*, Right valve, ×2.8, rubber cast from mold in limestone concretion, L.S.J.U. loc. 2575, NE cor. SE ¼, sec. 23, T. 16 S., R. 12 E., M. D. B. & M., Fresno County, California; hypotype 7369. (p. 65)

5—Acila (Truncacila) sp. D. Upper Cretaceous near Martinez, Contra Costa County, California; L.S.J.U. loc. 2180, in railroad cut 500 feet west of Santa Fe Railroad tunnel above Franklin Canyon Inn. Rubber cast from mold of left valve, ×2.5; details of profile uncertain; hypotype 7368. (p. 65)

6, 8—Acila (Truncacila) sp. F. Upper Cretaceous. Calif. Acad. Sci. loc. 950, San Antonio del Mar, Baja California, Mexico. *6*, Right valve, ×1.7, of specimen 26 mm. long; *8*, enlarged view of anterior portion, ×2.8, to show ribbing; hypotype 6023, Calif. Acad. Sci. (p. 66)

5906, Stanford Univ. Paleont. Type Coll., a crushed specimen about 19 mm. long, 16 mm. high, illustrated on plate 9, figure 2.

The specimen collected by Birch came from 500 feet stratigraphically below the top of the Moreno formation. This would be the Marca shale member of the Moreno formation of this area, which according to Payne (written communication) is overlain by the Dos Palos shale member and is underlain by the Tierra Loma shale member, below which, in turn, is the Mercy sand lentil. Payne believes that this *Acila* from the Marca member is geologically younger than *Acila princeps*.

Acila (*Truncacila*) sp. E (pl. 9, fig. 4) is 17 mm. long, 12 mm. high, thus falling into the general size category of *Acila demessa*. Viewed posteriorly, however, the Marca specimen has radial ribs (450 ± microns wide) continuing to the margin of the valve, whereas in *demessa* the ribless area in the "escutcheonal" region is a striking morphologic feature. Finally, the sculpturing of *Acila* sp. E is coarser than that of *demessa*. Compared with *A. princeps*, the smaller size and comparatively coarser ornamentation will separate the species.

Other specimens referred to *Acila* sp. E were generously donated by Arthur S. Huey from the Superior Oil Company well "Ciervo Unit Plan" No. 1, 330 feet north, 2156 feet west of the SE corner sec. 20, T. 16 S., R. 13 E., M.D.B.&M., depth (approximate) 5220 feet, associated with numerous specimens of *Siphogenerinoides*. The stratigraphic position is estimated to be 810 feet below the top of the Moreno formation.

Comparison with Acila (*Truncacila*) *sp. F.*—The specimen figured on plate 9, figures 6, 8, from Baja California, Mexico,[1] is the one which Schenck (1936-b, pp. 49–50) had identified as *A. demessa*. According to F. M. Anderson (as transmitted by L. G. Hertlein) the strata at the locality are upper Campanian in age. Measurements are as follows: length, 26 mm.; height, 20 mm.; radial ribs near middle of the ventral margin, 430 microns in width. Compared with *A. princeps* this specimen differs in profile and ornamentation. Its large size, shape and ornamentation are the reasons for now excluding it from *A. demessa*.

Comparison with Acila hokkaidoensis (*Nagao*).—The new species approaches the Japanese species in size. The holotype of *hokkaidoensis* is 30 mm. long and 22 mm. in height; the largest paratype measures 30 mm. in length, 20 mm. in height, and 10 mm. in thickness (two valves). Thus, *princeps* differs in height-length relations and is more inflated than *hokkaidoensis*. The two species differ somewhat in profile and ornamentation.

[1] California Academy of Sciences Locality 950: Hard lens about 1 foot thick outcropping behind old distillery on Johnson Ranch at San Antonio del Mar, Lower California, Mexico. Upper Cretaceous mollusks collected by E. K. Jordan and L. G. Hertlein, January, 1926.

AGE AND ORIGIN OF THE SANDSTONE AT LOCALITY 2372

The precise dating of the sand lentil with *Acila princeps* at locality 2372 in terms of the European standard of the Cretaceous is not possible with the limited data now in hand, although certain inferences may be offered for testing. The "*Acila*-scale" would date the sandstone as Aptian or younger, as the oldest known *Acila* is Aptian. The fossiliferous beds of the upper Panoche formation, stratigraphically below the sandstone carrying the new species, are believed to be Campanian in age. *Siphogenerinoides whitei* Church from the shale 260 ± feet stratigraphically above the locality of the new species is closely related to *Siphogenerinoides cretacea* Cushman from the lower Colon shale (possibly Campanian) of Venezuela. The foraminiferal faunule from this superjacent shale contains enough species to warrant a correlation with at least a part of the type Tierra Loma shale member of the Moreno formation, where late Cretaceous reptiles have been collected and reported upon by Stock (1941). The mollusks associated with *Acila princeps* are thought to be restricted to the Upper Cretaceous. Although available evidence proves that the sand lentil with this new nuculid pelecypod is late Cretaceous in age, only indirect reasoning permits the surmise that it is Maestrichtian.

Refined correlations of finely-spun lithogenetic units such as the sand lentil with *Acila princeps* with others of the Cretaceous

in California are inconclusive at this time. Perhaps, however, a few of the occurrences of *Acila demessa* will be suggestive of synchronizations.

The uppermost sandstone member of the Panoche formation at its type area, as defined by Anderson and Pack (1915), carries abundant specimens of *Acila demessa* in association with *Baculites, Glycymeris veatchii, Hamites ellipticus, Parallelodon* cf. *vancouverensis,* and *Turritella chicoensis* var., at L.S.J.U. locality 2251 (600 feet south, 700 feet west of the NE cor. sec. 12, T. 15 S., R. 11 E., M.D.M., Fresno Co.). This is the assemblage that occurs in the upper member of the Panoche formation, as mapped by Payne, in the Charleston School quadrangle.

G. D. Hanna and J. H. Show collected *A. demessa* from California Academy of Sciences locality 1552, sec. 28, T. 26 S., R. 18 E., M.D.M., 500 feet west of center of section 28, in the Panoche formation. This is in the area of "Knoxville-Chico" rocks mapped by Arnold and Johnson (1910) at the north end of Shale Hills.

Acila demessa occurs in the type Chico formation about 1250 feet above its base, as measured by Taff, Hanna, and Cross (1940). The specimens are from C. A. S. locality 27838 (sec. 23, T. 23 N., R. 2 E.) on Big Chico Creek. From the same locality those authors figure specimens of "*Ammonites*" *chicoensis, Baculites chicoensis, Oligoptycha obliqua, Anchura falciformis, Tenea inflata,* and *Trigonocallista varians.* The "*Ammonites*" is *Submortoniceras,* according to Siemon Wm. Muller (personal communication), and is Campanian in age.

In Shasta County, Redding region, Popenoe has collected numerous specimens of *Acila,* some of which are certainly *demessa.* He has stated (written communication) that the total stratigraphic range of *Acila demessa* in that area is about 1100 feet.

In the Santa Ana mountains, Corona quadrangle, Orange County, Popenoe has collected *Acila demessa* (pl. 9, figs. 3, 7) from C. I. T. locality 974 (middle south line sec. 29, T. 5 S., R. 7 W.), locality 975 (300 feet northwest of loc. 974), and locality 976 ($NE\frac{1}{4}$ $NE\frac{1}{4}$ sec. 19, T. 5 S., R. 7 W.), about 50–75 feet above the Pleasants member of the Williams formation. The range of the species, its occurrences at other localities, and associated fossils are given by Popenoe (1942). Among the many species found with *A. demessa* in the Pleasants member are *Baculites, Clisocolus cordatus, Cymbophora ashburnerii, "Fulgur" hilgardi, Glycymeris veatchii, Gyrodes expansus, Legumen ooides, Metaplacenticeras pacificum, Oligoptycha obliqua, Perissitys brevirostris,* and *Turritella chicoensis* (flat-whorled variety).

The subjacent upper Holz shale carries *Acila demessa* (p. 9, fig. 1) at C. I. T. locality 1059, between Santiago and Williams canyons, about 4650 feet N. 62° W. of the dam one-fourth mile upstream from the mouth of Harding canyon, Corona quadrangle. The molluscan fauna of the upper Holz shale, according to Popenoe, includes *Clisocolus cordatus, Cymbophora ashburnerii, Flaventia lens, Glycymeris veatchii, Tenea inflata, Turritella chicoensis perrini,* and many other species. No specimens of *Acila* were recorded from the middle and lower Holz shale nor from the subjacent Baker Canyon sandstone member of the Ladd formation. The recorded stratigraphic range of *Acila demessa* in the Santa Ana mountains is thus provisionally estimated to be approximately 300 feet.

The careful work by Popenoe seems to have established the Teilzone of *Acila demessa* in the Santa Ana mountains and in Shasta County. The writer is struck by the fact that the fauna of the Pleasants sandstone is closely comparable with that recorded by Schenck (1936-b, p. 49) from the type locality of *A. demessa* in Butte County. He is also impressed by the similarity of these two faunas with the assemblages from the upper sandstone member of the Panoche formation at its type area and from the upper Panoche, as mapped by Payne, in the Charleston School quadrangle, well below the sandstone with *A. princeps.* Hence, the conclusion is reached that *Acila princeps* is geologically younger than *Acila demessa.*

If such correlations as have been drawn in this paper are correct, then it would seem possible to propose a sequence of species of *Acila* in California. The oldest known *Acila* is the one from Contra Costa County here described as *Acila* (*Truncacila*) sp. D. Next in chronological order is *Acila* (*Truncacila*) *demessa* Finlay. Still younger is *Acila* (*Trun-*

cacila) *princeps* Schenck. The youngest Cretaceous species so far collected is the one described as *Acila* (*Truncacila*) sp. E from the Marca shale member of the Moreno formation.

Finally, a possible origin of the sandstone at locality 2372 may be inferred from the distribution of Recent specimens of *Acila* and from the petrographic study of Krauskopf. The hypothesis is that the sand was deposited rapidly without much weathering in the late Cretaceous sea between 8 and 800 fathoms, in water temperatures probably lower than 72° Fahrenheit and higher than 34° F. The sand may have been laid down in the lower neritic or upper bathyal zone in temperate waters.

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MARINE INVERTEBRATE FAUNAS OF THE BURIED BEACHES NEAR NOME, ALASKA

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ABSTRACT—The large fossils from the buried beaches near Nome, Alaska, are allocated to their respective positions in the sequence of deposits, and the Mollusca, Brachiopoda, Bryozoa, and Cirripedia are described and illustrated. New forms are described by MacNeil in the gastropod genera *Cylichnella* (*Bullinella*), *Oenopota*, *Mohnia*, *Columbella* (*Astyris*), *Epitonium* (*Boreoscala*), *Odostomia* (*Iolaea*), *Tachyrhynchus*, and *Solariella* (*Machaeroplax*); and in the pelecypod genera *Crenella*, *Astarte*, *Cardita* (*Cyclocardia*), and *Cardium* (*Cerastoderma*). A new form is described by Pilsbry in the cirrepede genus *Verruca*. It is inferred from the fauna that the relative ages of the beaches determined on physical grounds is correct, i.e., from younger to older, the Second Beach, the Intermediate Beach, and the Inner Submarine Beach; further, that the age of the Intermediate and Inner Submarine Beaches is Pliocene and of the Second Beach possibly Pleistocene. The fauna suggests that warmer waters than those of the present prevailed while the beaches were forming.

CONTENTS

	Page
Introduction	69
Geologic history, by John B. Mertie, Jr.	69
Age and probable temperature conditions, by F. S. MacNeil	73
Fossil localities, by John B. Mertie, Jr.	77
Description of fossils, except Cirripedia, by F. S. MacNeil	79
Description of fossil Cirripedia, by Henry A. Pilsbry	94

INTRODUCTION

THIS PAPER presents the results of a study of collections of larger invertebrates made from the buried beaches near Nome, Alaska, by John B. Mertie, Jr., in 1940, and of a restudy of collections made by F. L. Hess in 1905, F. H. Moffit in 1906, and E. M. Kindle in 1908.

Previous publications dealing with the larger invertebrates from the area are by Moffit (1913) and Dall (1919).

The Foraminifera from the collections made by Mertie in 1940 were described by Cushman (1941).

To the present paper Mertie has contributed the chapters on the geologic history and the localities; MacNeil the chapter on interpretation of the fauna and the description of the Mollusca, Brachiopoda, and Bryozoa; and Pilsbry the description of the Cirripedia.

GEOLOGIC HISTORY

By John B. Mertie, Jr.

The geologic history of the coastal province of Alaska, bordering upon Bering Sea, comprises a long and involved series of events that took place in Tertiary and Quaternary time. A complete record of these happenings has not yet been obtained, but enough is now known to sketch roughly the general geologic and geomorphic history. This sketch is based in part upon the older work of the Geological Survey in the Nome and nearby areas, done in the years between 1899 and 1908; and in part upon four years of recent work by the writer in the period between 1935 and 1940.

Diastrophism and the effects produced by changing meteorologic conditions are the fundamental processes that have affected the coastal province of Seward Peninsula, though farther south, in the country bordering upon Bering Sea, vulcanism has also played an important role. The sequence and magnitude of these processes are only im-

perfectly and incompletely known, yet certain results are well recognized. These include folding and faulting of the country rock, eustatic and local changes in sea level, with accompanying changes in the base level of erosion, glaciation, stream and shore erosion, sedimentation, and many other features. Some of the more noteworthy of these geological effects are sketched herewith.

Little is known of the early Tertiary history of Seward Peninsula. No marine sediments of Paleocene, Eocene, Oligocene or Miocene age have been recognized, but some terrigenous sediments of early Tertiary age have been found in hinterland areas. In addition, there is a series of old erosion surfaces ranging in altitudes from about 1100 feet almost to sea level. Some workers have mentioned still higher erosion surfaces at altitudes of 2000 to 2700 feet, but these are probably the composite images of a whole series of preexisting land surfaces. The old erosion surface at or near the 1100-foot level may possibly date back to the Miocene, but all of the sediments that may originally have laid upon it have been removed by erosion. These older erosion levels might be interpreted to indicate that the base level of erosion was much higher in pre-Pliocene Tertiary time than at present, but other recently acquired evidence leads to the belief that these higher surfaces are more probably due to upthrows resulting from intermittent faulting.

The earliest base level of erosion that is both preserved and paleontologically dated is the bedrock surface at Nome upon which the Pliocene marine deposits rest. The conditions at and near Nome may best be understood by visualizing a sloping foreland more than three miles wide, bounded on the north by low hills and on the south by Norton Sound, an arm of Bering Sea. The bedrock underlying this foreland is covered by alluvial deposits ranging in thickness from 30 to 120 feet, and of these the lower few feet superjacent to bedrock are beach gravels, mainly of Pliocene age. The overlying deposits are both marine and terrigenous in origin, the terrigenous deposits lying for the most part closer to the hills. Starting 3 miles from the sea, a bedrock profile drawn southward toward the sea shows an initial altitude of about 70 feet above sea level. The bedrock thence slopes gently toward the sea, passing below sea-level about three-fourths of a mile north of the present beach. Near the north end of this profile, at the site of the so-called Third Beach, an alluvial cover about 85 feet thick consists of 3 to 5 feet of marine beach gravels overlain mainly by terrigenous deposits of Quaternary age. At the north end of the Third Beach, this gently sloping bedrock surface is terminated abruptly by a bedrock cliff, about 14 feet high, which apparently represents an old sea cliff. Upon the sloping bedrock surface are a number of sites at which accumulations of gold were concentrated by an advancing Pliocene sea.

The sea apparently advanced in several steps or pulses, pausing long enough at the end of each pulse to produce well-defined beaches, which are characterized by concentrations of heavy minerals, including gold. These bedrock beaches, named in order from oldest to youngest and from south to north, are known as the Outer Submarine, Inner Submarine, Intermediate, Monroeville and Third beaches. The youngest bedrock beach lies at the base of the above-mentioned bedrock cliff. The approximate altitudes of bedrock below these five beaches are respectively, −34, −20, +21, +40, and + 70 feet below and above sea level. Other less well defined beaches, lying between these, and also north of the Third Beach, have been recognized, but have not received formal designations. As the sea advanced, the regional base level of erosion was elevated, and the older deposits were covered by later Pliocene sediments. After the Third Beach was formed, the sea is believed to have retreated rapidly to some strand line seaward of the present one, thus preserving most of marine Pliocene sediments, which were subsequently covered by younger deposits of terrigenous and marine origin.

About half a mile north of the present beach at Nome is another old beach, called the Second Beach, which was formed, not on bedrock, but atop preexisting sediments of Pliocene and Pleistocene age. This beach was formerly considered to have originated at the end of a period of marine regression that followed the Pliocene invasion of the

sea. At this time a period of relative stability was conceived to have occurred, and the sea gradually cut back into the alluvial deposits of the Nome foreland, forming a high sea cliff. At the same time a marked concentration of gold and other heavy minerals was effected south of the sea cliff, at an altitude of about 37 feet above present sea level. Thereafter the strand line was believed to have migrated seaward a short distance south of the present beach and finally to have moved landward by wave cutting to its present site.

New evidence now indicates that the Pliocene sea, after the formation of the Third Beach, retreated rapidly to some strand line well south of the present beach; and thereafter, in Pleistocene time, the strand line moved northward to the general site of the Second Beach. This interpretation implies that the time interval between the retreat of the sea in Pliocene time and its advance in Pleistocene time was one of considerable duration, during which time certain terrigenous deposits, including some of glacial origin, were deposited upon the marine Pliocene deposits. It also implies that the Second Beach was formed as a result of transgressive movement of the sea, accompanied by a rising base level of erosion.

A new geomorphic interpretation is also offered regarding the movement of the strand line after the formation of the Second Beach. From evidence recently made available at Nome and elsewhere on Bering Sea, it now appears probable that after the formation of the Second Beach, the strand line retreated far seaward of its present site, materially reducing the area of Bering Sea, and possibly draining inlets like Norton Sound and Port Clarence. This regional lowering of the base level of erosion may also have been sufficiently great to render Bering Strait much less of a barrier to human passage. The latest migration of the strand line has been northward from some position now below the sea to the site of the present beach. This movement has therefore been a landward transgression of the sea accompanied by a rising base level of erosion, and not merely a landward movement of the strand line, resulting from wave cutting.

The hypothesis above outlined regarding the post-Miocene movements of the strand line in the Nome area deals only with major geomorphic changes but probably still fails to enumerate all the major movements of the strand line. In addition, no account whatever is taken of minor oscillations of the strand line, of which there may have been many. In general, however, the hypothesis implies that at least three landward and two seaward migrations of the strand line have occurred in the Nome area in post-Miocene time. But neither the Pliocene bedrock beaches nor the Pleistocene beach on alluvium have been traced for any considerable distance northwest or southeast of Nome. In the vicinity of Bering Strait, from 50 to 100 miles northward, bare bedrock with only a veneer of fluviatile materials on the valley floors extends practically to the sea, so that neither Pliocene nor Pleistocene marine deposits can possibly be present. Moreover, in this area there is cogent evidence of the presence of fault-line scarps more or less parallel to the coast and of cross faulting nearly normal to the coast. About 400 to 450 miles to the southward, however, thick deposits of glaciofluviatile materials of Pleistocene age extend to the sea; and at Bristol Bay, such deposits are underlain by flexed and gently folded marine Pliocene beds.

Both epeirogenic movements of the land and eustatic changes in sea level may also enter into the geomorphic history of this region. But the marked differences in physiographic and structural conditions that exist between the Nome and contiguous areas suggest strongly that the dominant structural control has been the presence or absence of local warping and faulting at different sites. These conditions make it necessary to emphasize that the geomorphic history of the Nome area is not necessarily applicable elsewhere along the shores of Bering Sea.

Glaciation has also played an important role in the geologic history of this region. The Kigluaik and Bendeleben Mountains of Seward Peninsula and the Tikchik and Oklune Mountains northeast of Bristol Bay have been the sites of active glaciation during the Wisconsin stage of the Pleistocene. In the Nome area, the glaciers that origi-

nated in the Kigluaik Mountains are not definitely known to have extended as far south as the present shores of Norton Sound; but if they did so, the ice was in the form of tongues that occupied the valley of Nome River and possibly the valley of Snake River. But many large scratched and grooved glacial erratics lie below the surface of the Nome foreland; and some of these are deeply buried, occurring in contact with or very close to the tops of the older Pliocene marine deposits. They also underlie the marine deposits of the Second Beach. Other such boulders are also present in the low hills north of the foreland at altitudes ranging from 600 to 1000 feet above sea level. These boulders were formerly considered to have been ice rafted to their various present positions. For the higher boulders, this explanation fails because it is now believed that the sea never reached their present sites. Moreover, the Wisconsin ice apparently was not thick enough close to the coast to account for the presence of these erratics. As for the erratic boulders that are deeply buried in the Nome foreland, ice rafting would imply that they were deposited before the Second Beach was formed. And in view of the age of the Second Beach, as determined by fossil evidence, this in turn would imply that these erratics are relics of a pre-Wisconsin glacial stage.

Recently, the writer has obtained evidence that indicates the existence of an older stage of Pleistocene glaciation in this region. The type locality is in and about the York Mountains, about 80 miles northwest of Nome. These mountains were not glaciated by Wisconsin ice, and it is for that reason that the evidence of the older glaciation has not been obliterated or obscured. The existence of older glaciation in an area that could not support Wisconsin glaciation also suggests that the older ice fields were the more extensive. Applying these deductions to the Nome area, it is inferred that a pre-Wisconsin glaciation existed in the Kigluaik Mountains, and that this ice extended to and probably beyond the present strand line. Under this hypothesis, the deeply buried erratics in the Nome foreland could have been deposited either by direct glacial action, or by ice rafting, or by both.

As some of these glacial erratics lie below the marine deposits of the Second Beach, this beach was therefore formed after the glacial stage during which these boulders were deposited. Regarding the Second Beach as a phenomenon due to transgression of the sea, it might then be coupled with an absolute or eustatic rise in the level of the sea; and this in turn, suggests its formation during an interglacial stage, when melted ice might have been available to produce such a rise in sea level. But only two glacial stages are inferred to have existed in this region. Therefore the Second Beach was probably formed during some interglacial stage between the older glaciation above postulated and the Wisconsin stage. It is not yet possible to correlate this interglacial stage with the Aftonian, Yarmouth or Sangamon interglacial stages because the physiographic evidence suggests that the older glacial stage occurred a long time before the Wisconsin ice developed. This interpretation appears not to be inconsistent with the evidence furnished by the fossils.

The geomorphic history of the coastal province of Seward Peninsula, with special reference to the Nome area, may be briefly and very generally summarized as follows:

1. Seward Peninsula has been a land mass from the beginning of the Tertiary period to the present day; but during early Tertiary time, the strand line of Bering Sea remained seaward of its present site. Normal erosion was continuous, but intermittent faulting occurred in middle and late Tertiary times.

2. In early Pliocene time the sea transgressed landward in a pulsatory manner so as to form the bedrock beaches at Nome.

3. In late Pliocene or early Pleistocene time regression of the sea from the Nome foreland caused the reestablishment of normal eluvial and fluviatile erosion and sedimentation. Faulting continued.

4. Extensive regional glaciation of pre-Wisconsin Pleistocene age began in the Kigluaik and Bendeleben Mountains and extended to and probably well beyond the present strand line in the Nome area.

5. The ice withdrew, and normal eluvial and fluviatile erosion and sedimentation were resumed.

6. The sea transgressed landward, and formed the Second Beach at Nome.

7. The sea withdrew and normal eluvial

and fluviatile erosion and sedimentation were resumed.

8. Wisconsin glaciation began. There was active glaciation in the Kigluaik and Bendeleben Mountains. Tongues of ice came down the major valleys and extended possibly as far south as the present shore of Norton Sound.

9. The Wisconsin ice withdrew, and normal eluvial and fluviatile erosion and sedimentation were resumed.

10. The sea transgressed landward to the present strand line.

AGE AND PROBABLE TEMPERATURE CONDITIONS

By F. S. MacNeil

Grant and Gale (1931, p. 57) questioned Dall's earlier age assignment of the Nome beaches to the Pliocene, suggesting at the same time that they would probably prove to be Pleistocene in age. The fairly high percentage (30 and possibly as high as 43½ percent) of extinct species for all beaches bears out Dall's belief, however, that some of the Nome beaches at least are as old as Pliocene.

Owing to the small, incomplete collections from most localities and particularly from localities on the Third and Second Beaches, percentages of species in common with other beaches and with the Recent fauna might be misleading. Four species, *Littorina palliata* (Say), *Littorina* (*Algaroda*) aff. *L. squalida* Broderip and Sowerby, *Serripes gronlandicus* (Bruguière), and *Pholadidea penita* (Conrad), all living species, are found in the Second Beach but not in the older beaches. Recent *Littorina palliata* is known only on the Atlantic coast, however, and not on the Pacific. Sixteen of the remaining 20 known species from the Second Beach are identifiable with some certainty, and of these 4 are extinct and 3 others are possibly extinct or very similar to Recent species.

Fifty-nine of the 65 species known from all beaches occur in the Inner Submarine Beach and the Intermediate Beach, of which 18 are known only from the Inner Submarine, 20 only from the Intermediate, 2 in the Inner Submarine and questionably in the Intermediate, 3 in the Intermediate and questionably in the Inner Submarine, and 16 species common to both beaches. Of the species of the Second Beach, 7 are common to both the Intermediate and Inner Submarine beaches, 4 more questionably common to both, 9 common to the Intermediate Beach alone, and none common to the Inner Submarine beach alone.

Of 39 Inner Submarine Beach species, 13 are extinct, 5 more are questionably extinct, 11 are living and 10 are indeterminable. From the Intermediate Beach 41 species have been recognized, of which 11 are extinct, 5 are questionably extinct, 19 are living, and 6 are indeterminable.

On the basis of present collections the percentages of extinct species for the three best-known beaches are as follows: Inner Submarine Beach, 33 to 46 percent; Intermediate Beach, 27 to 39 percent; Second Beach, 16.5 to 24 percent. From these figures it appears that the relative ages of the beaches as determined by field geologists is correct. The percentage of extinct species in both the Inner Submarine Beach and the Intermediate Beach falls well within the limits generally taken to indicate pre-Pleistocene age, and the writer is therefore in agreement with Dall that at least these beaches are of Pliocene age. The smaller percentage of extinct species from the Second Beach, though based on obviously incomplete collections, together with the fact that the shells from the Second Beach, though much worn, are considerably less leached than those from other beaches, suggest that the Second Beach may be of Pleistocene age. The occurrence of a *Littorina*, which although living is not living on the same side of the continent, might argue for an early rather than a late Pleistocene age, however.

Any concept of the temperature conditions in the Nome region at the time the beaches were formed should be based mainly on the habitat of the species still living and secondly on the habitat of the nearest Recent relatives of the extinct forms. Strangely enough, the species that point most strongly to a warmer environment are those of the second category. The forms still living, with the exception of *Pododesmus* (*Monia*) *macroschisma*, *Taras orbellus*, and *Pholadidea penita*, are all within their Recent range. *Pododesmus* (*Monia*) *macroschisma* does not now occur north of

KNOWN OCCURRENCE OF NOME BEACH SPECIES

MOLLUSCA	Living—L Extinct—E Extinct? close to living—EC	Inner Submarine Beach					Uncertain		Intermediate Beach						Gravel 50′ below Surface	Third Beach	Nearest to Third Beach	Second Beach				
		7620	7621	7623	7624	14865	7622	9250–53	4538	5074	5313	7477	7619	14866	4537	5076	5075	3752	5077	5078a	5078	7618
Cylichnella (*Bulinella*) *nucleola nomeana* MacNeil, n. subsp.	EC					×																
Oenopota mertiei MacNeil, n. sp.	E					×						?										
Propebela aff. *P. popovia* (Dall)	EC					×																
Propebela? sp. indet.	?					×																
Admete couthouyi (Jay)	L					×								×								
Admete middendorffiana Dall	L					×																
Mohnia moffitti MacNeil, n. sp.	E					×																
Plicifusus (*Microfusus*) cf. *P. brunneus* (Dall)	L					×																
Colus (*Aulacofusus*) *spilsbergensis* (Reeve)	L								×					×								
Colus (*Latisipho*) sp. indet.	?													×								
Chrysodomus mesleri Dall	E									×			×	×								
Chrysodomus sp., juvenile[a]	?							×						×								
Buccinum sp. indet.[b]	?			×		×								×					×			
Columbella (*Astyris*) *rosacea sewardensis* MacNeil, n. subsp.	E					×																
Trophon (*Boreotrophon*) *beringi* (Dall)	L					×								×								
Trophon (*Trophonopsis*) cf. *T. tenuisculptus* Carpenter	E?													×								
Thais (*Nucella*) *nomeana* Dall	EC		×				×			×			×	×				×			?	
Epitonium (*Boreoscala*) *greenlandicum smithi* MacNeil, n. subsp.	E					×																
Melanella sp.	?					×																
Trichotropis insignis Middendorff	L									×			×	×					×			
Trichotropis bicarinatus (Sowerby)	L					×								×								
Odostomia (*Iolaea*) *amiantopsis* MacNeil, n. sp.	E					×																
Tachyrhynchus erosus major Dall	L					×								×								
Tachyrhynchus lacteolus nomensis MacNeil, n. subsp.	E					×						×										
Littorina palliata (Say)	L																	×			×	
Littorina (*Algaroda*) aff. *L. squalida* Broderip and Sowerby	L																	×			×	
Natica (*Cryptonatica*) aff. *N. janthostoma* Deshayes?	EC								×	×			×	×								
Natica sp. indet.	?					×								?								
Lepeta (*Cryptoctenidia*) *magna* Dall	E									×	×		×	×							×	
Solariella (*Machaeroplax*) *varicosa nomeana* MacNeil, n. subsp.	E					×																
Cyclostrema, n. sp.?	EC					×																
Mölleria, n. sp.?	EC					×																
Buccinum? sp. (possibly a turrid)	?					×																
Yoldia (*Yoldiella*) *siliqua* (Reeve)	L													×								
Pecten (*Chlamys*) *islandicus* Müller	L								×			×				×				×		
Pecten (*Chlamys*) *lioicus* Dall	E														×							
Pecten (*Fortipecten*) *hallae* Dall	E							×														
Pecten (*Manupecten*) *kindlei* Dall	E								×	×	×		×	×								?
Pododesmus (*Monia*) *macroschisma* (Deshayes)	L						×		×	×	×		×	×					×			×

[a] Unidentifiable *Chrysodomus* fragments are present in several collections but only those of *C. mesleri* are included in the above list (see p. 81, pl. 10, figs. 18, 19).
[b] May not be the same species at all stations.

KNOWN OCCURRENCE OF NOME BEACH SPECIES—*Continued*

		Inner Submarine Beach					Uncertain		Intermediate Beach						Gravel 50′ below Surface	Third Beach	Nearest to Third Beach	Second Beach				
MOLLUSCA	Living—L Extinct—E Extinct? close to living—EC	7620	7621	7623	7624	14865	7622	9250–53	4538	5074	5313	7477	7619	14866	4537	5076	5075	3752	5077	5078a	5078	7618
Crenella nomeana MacNeil, n. sp.	E					X																
Mytilus (*Mytilus*) *edulis* Linnaeus	L		X			?	X			X				X						X		
Astarte actis Dall	EC									X	X	?	X	XX							X	X
Astarte hemicymata Dall	E		?	X		?						X		XX								
Astarte nortonensis MacNeil, n. sp.	E		?					X				X		XX								
Astarte leffingwelli Dall	E													XX								
Astarte sp. aff. *A. fabula* Reeve	L	X			X	?																
Astarte (*Rictocyma*) *diversa* Dall	E			X		XX						X		XX								
Cardita (*Cyclocardia*) *crebricostata* (Krause)	L					XX		X		X		X		X				?				
Cardita (*Cyclocardia*) *crebricostata nomensis* MacNeil, n. subsp.	E					XX			XX													
Cardita (*Cyclocardia*) *subcrassidens* MacNeil, n. sp.	E		?			XXX	X		XX					X						X		XX
Cardita (*Cyclocardia*) sp.	?																					
Taras cf. *T. orbellus* (Gould)	L					XXX																
Cardium (*Cerastoderma*) *ciliatum brooksi* MacNeil, n. subsp.	E		X	X		X	X		X	X		?	X	X						X	X	X
Serripes grönlandicus (Bruguière)	L																		X			
Tellina (*Peronidia*) *lutea* Gray	L													XX								
Macoma middendorffi Dall	L		?				XX		XX	XX	X		XX	X				X			XX	XX
Macoma incongrua (*Martens*)	L						XX		XX	XX			XX								XX	XX
Macoma calcarea (Gmelin)	L			?								X										
Siliqua aff. *S.* "*media* Gray" Dall	L									XX				XX								
Spisula (*Mactromeris*) aff. *S. polynyma* (Stimpson)	EC												X	XX							X	X
Mya sp. indet.	?			X		X				XX		X		XX					X		X	X
Panomya ampla Dall	L								X	XX				XX							X	X
Saxicava arctica (Linnaeus)	L	X				X						X		XX				XX		X		
Saxicava pholadis (Linnaeus)	L									X								X				
Pholadidea penita (Conrad)	L													X								
BRACHIOPODA																						
Hemithyris psittacea alaskana Dall									X							XX	X		X			X
Diestothyris aff. *D. frontalis* (Middendorff)						X								X		XX						
BRYOZOA																						
Myriozoum subgracile d'Orbigny												X		XX								
Schismopora sp.														XX								
VERMES																						
Serpula sp.														X								
CIRRIPEDIA																						
Balanus rostratus alaskensis Pilsbry						XX	X		X	X		X	X	XX		X		X		X	X	X
Balanus crenatus (Bruguière)						X								XX								
Verruca alaskana Pilsbry, n. sp.														X								

southern Bering Sea, *Taras orbellus* has not been reported north of the Pribilof Islands, and *Pholadidea penita* has not been identified north of the Alaskan Peninsula, although the subspecies *concamerata* and the closely related *P. ovoidea* occur in Bering Sea.

Several of the extinct species, however, are most closely related to forms now living in considerably more temperate and even subtropical waters. Among these are *Tachyrhynchus lacteolus nomensis*, closely related to *T. lacteolus*, which does not occur north of the Alaskan Peninsula; *Pecten kindlei*, closely related to *Pecten swifti* found in the Pliocene to Recent of Japan, and to three varieties, *etchegoini*, *parmeleei*, and *nutteri*, from the Pliocene of California; *Pecten hallae*, closely related to *Pecten takahashii* from the Pliocene of Japan; *Astarte actis*, closely related to *Astarte rollandi*, reported living from the Pribiloff Islands to southeastern Alaska; and *Astarte hemicymata*, most closely related to *A. alaskensis*, now living from southern Bering Sea to Puget Sound. *Odostomia* (*Iolaea*) *amiantopsis* may not be closely enough related to *Odostomia* (*Iolaea*) *amianta* from Lower California for justifiable climatic comparison. In addition the new species of barnacle, *Verruca alaskana* Pilsbry, is the first species of the genus to be found either fossil or Recent north of Peru. The range of the Recent species cited, although not identical with the Nome beach forms, strongly suggests that warmer conditions prevailed in the region of Norton Sound when the beaches were formed than at the present time.

EXPLANATION OF PLATE 10

FIG. *1—Cylichnella* (*Bulinella*) *nucleola nomeana* MacNeil, n. subsp. Holotype, ×8, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499013. (p. 79)

2, 3—Oenopota mertiei MacNeil, n. sp. Holotype, ×3, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499014. (p. 79)

4—Propebela aff. *P. popovia* (Dall). Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499015, ×4 (p. 80)

5—Propebela? sp. indet. Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499016, ×3. (p. 80)

6—Mohnia? sp. Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499023 (=fig. 11?), ×3. (p. 80)

7–10—Admete couthouyi (Jay). *7*, Intermediate Beach, locality 14866, U. S. Nat. Mus. 499071, ×1½. *8*, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499018, ×3; *9*, *10*, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499019, 499020, ×4. (p. 80)

11—Mohnia moffiti MacNeil, n. sp. Holotype, ×3, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499022. (p. 80)

12—Admete middendorffiana Dall. Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499021. ×6. (p. 80)

13, 14—Plicifusus (*Microfusus*) cf. *P. brunneus* (Dall). Inner Submarine Beach, locality 14865, ×3; *13*, U. S. Nat. Mus. 499024; *14*, 499025. (p. 80)

15—Colus (*Aulacofusus*) *spitzbergensis* (Reeve), Intermediate Beach, locality 14866, U. S. Nat. Mus. 499026, ×1½. (p. 81)

16—Colus (*Latisipho*) sp. indet. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499027, ×1. (p. 81)

17, 21—Chrysodomus mesleri Dall. Intermediate Beach, ×1; *17*, locality 14866, U. S. Nat. Mus. 499028; *21*, locality 5074, U. S. Nat. Mus. 324412. (p. 81)

18, 19—Chrysodomus sp. Fragments, ×1. *18*, Intermediate Beach, locality 14866, U. S. Nat. Mus. 499029; *19*, uncertain horizon, locality 9253, U. S. Nat. Mus. 333047. (p. 81)

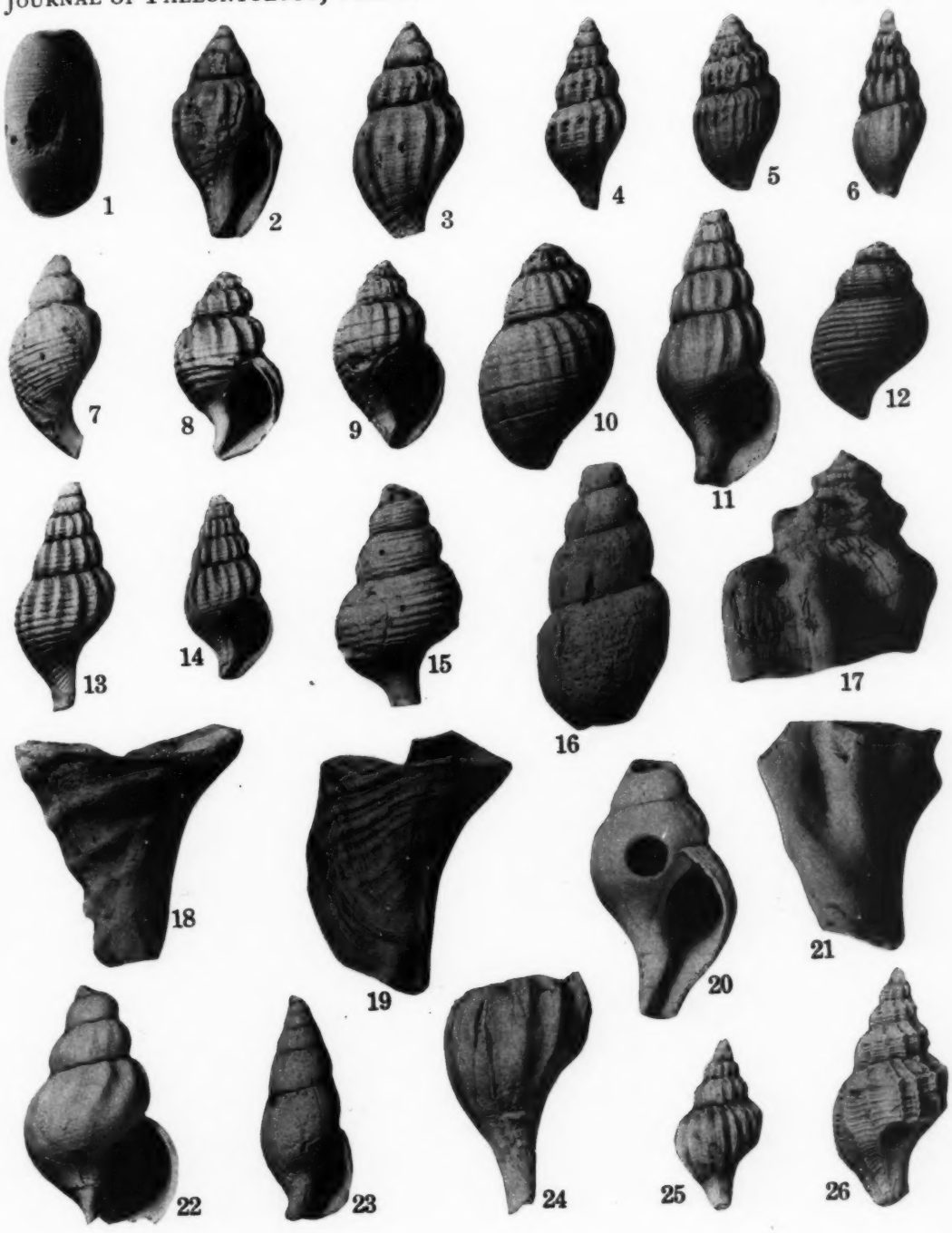
20—Chrysodomus sp. Juvenile, ×1½, Intermediate Beach, locality 14866, U. S. Nat. Mus. 499030. (p. 81)

22—Buccinum sp. indet. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499031, ×2. (p. 82)

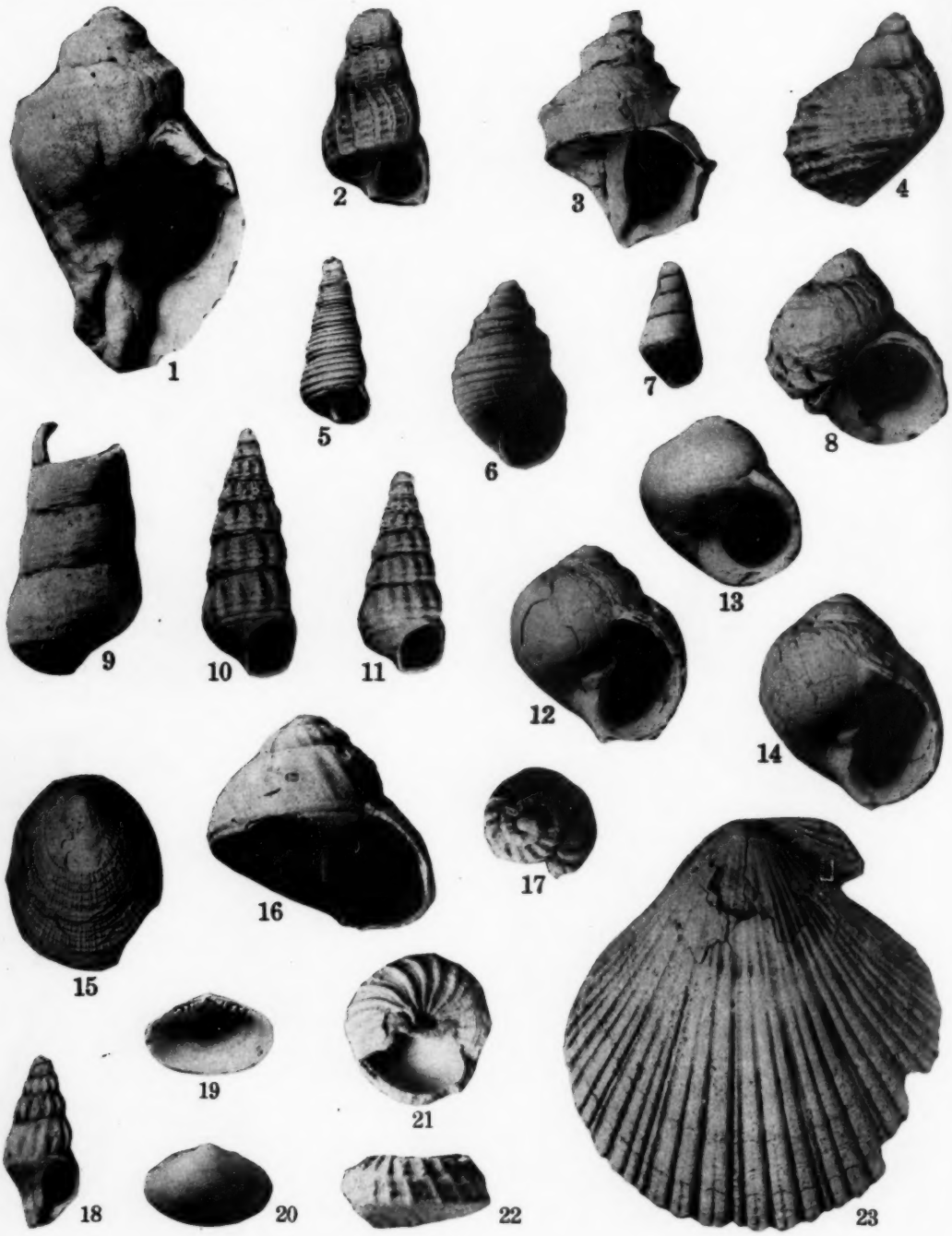
23—Columbella (*Astyris*) *rosacea sewardensis* MacNeil, n. subsp. Holotype, ×3, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499032. (p. 82)

24, 25—Trophon (*Boreotrophon*) *beringi* (Dall). *24*, Intermediate Beach, locality 14866, U. S. Nat. Mus. 499033, ×1½; *25*, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499034, ×2. (p. 82)

26—Trophon (*Trophonopsis*) cf. *T. tenuisculptus* Carpenter. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499035, ×1½. (p. 82)



MacNeil, Mertie, and Pilsbry, Fossils from Nome Beaches



MacNeil, Mertie, and Pilsbry, Fossils from Nome Beaches

LOCALITIES

By John B. Mertie, Jr.

Many of the geographic and geologic assignments of the older collections differ materially from those made by Dall in U. S. Geological Survey Professional Paper 125-C. These discrepancies were first discovered in attempting to locate and correlate several small collections that were not mentioned in that paper. Thereafter the writer spent several days studying the original locality descriptions of the collections cited by F. H. Moffit in U. S. Geological Survey Bulletin 533, and by W. H. Dall. In this connection, he examined the field notebooks of E. M. Kindle for 1908, and the determinations of Kindle's and Mesler's fossils, as stated originally in long-hand letters written by Dall on November 11, 1908, and January 7, 1909.

These original papers show the following facts. First, it appears that the numbers referred to by Dall in the above-mentioned etters are not entirely the same as those by which the fossils are now listed in the Museum; but the localities themselves, together with cross references to Kindle's field numbers in both systems of Museum numbers, and the character of the fossils make it possible to correlate the different sets of numbers. (Kindle's collections were registered twice, but the specimens bear only the last set of numbers and they are the ones used here.—F. S. M.)

The second fact is that Dall made erroneous assignments of most of these collections to the various beach lines of the Nome district. In particular, he referred collections 5074 and 7619 to the Second Beach, whereas they should have been referred to the Intermediate Beach. He also referred collections 5075 and 5076 to the Second Beach, when they should have been referred to the Third Beach. And finally he referred collections 7620 (printed 7260) and 7621 to the Second Beach, though they should have been referred to the Inner Submarine Beach. The new assignments given below were obtained from Kindle's original notes. Kindle also

EXPLANATION OF PLATE 11

FIG. *1—Thais* (*Nucella*) *nomeana* Dall. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499036, ×1. (p. 82)

2—Epitonium (*Boreoscala*) *greenlandicum smithi* MacNeil, n. subsp. Holotype, ×2, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499037. (p. 82)

3—Trichotropis bicarinatus (Sowerby). Intermediate Beach, locality 14866, U. S. Nat. Mus. 499041, ×1½. (p. 83)

4, 8—Trichotropis insignis Middendorff. Intermediate Beach, locality 14866; *4*, U. S. Nat. Mus. 499040, ×2; *8*, U. S. Nat. Mus. 499039, ×1½. (p. 83)

5, 9—Tachyrhynchus erosus major Dall. *5*, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499043, ×2. *9*, Intermediate Beach, locality 14866, U. S. Nat. Mus. 499044, ×1. (p. 83)

6—Odostomia (*Iolaea*) *amiantopsis* MacNeil, n. sp. Holotype, ×8, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499042. (p. 83)

7—Melanella sp. Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499038, ×6. (p. 83)

10, 11—Tachyrhynchus lacteolus nomensis MacNeil, n. subsp. Inner Submarine Beach, locality 14865, ×4; *10*, holotype, U. S. Nat. Mus. 499045; *11*, U. S. Nat. Mus. 499046. (p. 83)

12, 14—Natica (*Cryptonatica*) aff. *N. janthostoma* Deshayes? Intermediate Beach, locality 14866; *12*, U. S. Nat. Mus. 499047, ×1; *14*, U. S. Nat. Mus. 499048, ×1½. (p. 84)

13—Littorina palliata (Say). Second Beach, locality 5078, U. S. Nat. Mus. 324319, ×2. (p. 83)

15—Lepeta (*Cryptoctenidia*) *magna* Dall. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499049, ×1. (p. 85)

16, 17—Solariella (*Machaeroplax*) *varicosa nomeana* MacNeil, n. subsp. Inner Submarine Beach, locality 14865; *16*, holotype, U. S. Nat. Mus. 499050, ×6; *17*, paratype, U. S. Nat. Mus. 499062, ×10. (p. 85)

18—Buccinum? sp. Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499053, ×4. (p. 86)

19, 20—Yoldia (*Yoldiella*) *siliqua* (Reeve). Intermediate Beach, locality 14866, U. S. Nat. Mus. 499054, ×6; *19*, interior of left valve; *20*, exterior of right valve. (p. 86)

21, 22—Cyclostrema n. sp.? Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499051, ×10; *21*, basal view; *22*, lateral rear view. (p. 85)

23—Pecten (*Chlamys*) *islandicus* Müller, Intermediate Beach, locality 4538, U. S. Nat. Mus. 499055, ×1. (p. 86)

states that collections 22a and 33b, which correspond to Museum numbers 5077 and 5078, came from the Second Beach, as Dall states they did; but apparently these are the only collections by Kindle that are definitely known to have come from the Second Beach. These two collections are mentioned particularly, because they are certainly the youngest of the fossil shells from the Nome area; and if any of these collections may conceivably be of Pleistocene age, these should be the ones.

The true locality descriptions, as obtained from Kindle's notebooks and other original sources, are given herewith. The numbers are registered in the Cenozoic station book at the United States National Museum.

Localities

3752. Mine dump on claim 2, Peluk Creek, near Nome. Collector, F. L. Hess, 1903. The description suggests that this came from the *Second Beach*.

4537. "Gravels under tundra near Nome, Alaska, at a depth of 50 feet." F. H. Moffit, 1906. [This may be the collection which the records of the Geological Survey show was made by Moffit in 1906 from near Center Creek, about 2 miles from the shore of Bering Sea, probably from the *Intermediate Beach*.]

4538. Otter Creek, about 2 miles from shore of Bering Sea. Shells said to come from 54 feet below the surface and about 20 feet above sea-level. Description indicates that shells came from a locality about midway between the Intermediate and Monroeville beaches, but the altitude suggests that the shells came from the *Intermediate Beach*. Collector, J. J. Beaver (firm of Bole & Beaver), 1905. Given to F. L. Hess, and transmitted by F. H. Moffit in 1906.

5074 (7619). Mine dumps from the *Intermediate Beach*, on Center Creek. Position of shells in section not known, but it is stated in the field notes that the gravels worked at these mines lay at an altitude of 18 to 21 feet above sea level. Collector, E. M. Kindle, 1908.

5075. Black Diamond mine on southwest side of Tripple Creek, about 5½ miles northeast of Nome. Shells occur in a conglomerate bed 60 to 75 feet below the surface. Kindle states that these shells come from the *Third Beach*, but they actually occur *north of the Third Beach line*. They are nearer to the Third than to any other of the well-recognized beaches. Collector, E. M. Kindle, 1908.

5076. Prospect hole 280 yards southeast of the Black Diamond mine, about 5½ miles northeast of Nome. Surface of ground here about 25 feet lower than at locality 5075; and shells occur in a fine sand 30 to 40 feet below the surface. Kindle refers these shells, like those of 5075, to what he called the *Third Beach*. Collector, E. M. Kindle, 1908.

5077. Mine dump on *Second Beach*, 1½ miles east of Nome, and about midway between triangulation station 140 and Peluk Creek. (See U. S. Geol. Survey Bull. 533, plate 3.) Shells occur in a dark muck and coarse gravel. Collector, E. M. Kindle, 1908.

5078a. = 5077. Various prospect holes on Second Beach, from ¼ to 1½ miles east of Nome. Shells occur in fine sand and gravel. Collector, E. M. Kindle, 1908.

5313. Fossil shells from Vogel and Williams claim, Center Creek, Seward Peninsula, Alaska; 1½ miles north of seacoast and 32 feet below surface. Received from Alaska Yukon Exposition, 1909, through George P. Merrill, October 8, 1910. (No data are given as to the beach from which these shells were taken, but the fauna indicates the *Intermediate Beach*.)

7477. Dump of shaft 80 feet deep between Dry and Bourbon Creeks, 1 mile from beach at Nome. Collected by F. L. Hess, 1905. Description indicates that these shells came from the *Intermediate Beach*.

7618. Mine dump of the Gallatin Mine, about 1 mile north of Fort Davis, and near the junction of Florence Gulch with Otter Creek. No assignment to any definite beach line was made by Kindle, but the locality as given suggests that the shells may have come from either the *Second* or the *Intermediate Beaches*. Collector, R. D. Mesler (assistant to Kindle), 1908.

7619. = 5074. 7620. Mine dumps (Welch Mine, according to the station book) on the *Inner Submarine Beach*, ½ mile west of Nome. Collector, E. M. Kindle, 1908.

7621. Prospect holes near the mine dumps on the *Inner Submarine Beach*, ½ mile west of Nome. These are shallow holes, and none of them were as deep as the mine shafts, represented by collections 7623 and 7624. Collector, E. M. Kindle, 1908.

7622. Prospect holes near the Seiffert and Gibson mine, ½ mile northwest of Nome. Position of shells in the stratigraphic section not definitely stated, but the field notes led to the inference that the shells came from coarse sand and gravel that lay only 4 to 10 feet below the surface. Collector, E. M. Kindle, 1908.

7623. Seiffert and Gibson mine, on the *Inner Submarine Beach*, ½ mile northwest of Nome. Shells occur in bluish-gray fine-grained sandy "muck," in two beds separated by 8 or 10 inches of clay. Coarse gravel overlies the shell-bearing beds and formed the roof of the mine. Collector, E. M. Kindle, 1908.

7624. Mine dump at the Seiffert and Gibson mine, on the *Inner Submarine Beach*, ½ mile northwest of Nome. Collector, E. M. Kindle, 1908.

9250–53. From a buried Pliocene beach 20 feet below the present surface near Solomon River, Nome District, Alaska. Collector, Otto Halla, 1920. (Each of four species were given separate station numbers in this lot so that one, 9250, should suffice for all.) According to Dr. P. S. Smith, Chief Alaskan Geologist, Otto Halla was a mining man who operated mainly near Nome on the submarine beaches and not on Solomon River. He therefore believes that the locality "Solomon River" may be an error for "Snake River."

14865. *Inner Submarine Beach*, about 1 mile N. 60° W. of Nome. Shells collected from dredge tailings. Collector, J. B. Mertie, Jr., 1940.

14866. *Intermediate Beach*, between Center and Bourbon Creeks, and about 2 miles north of the mouth of Snake River. Shells collected from the dumps of a line of old drift mines trending N. 60° W. Collector, J. B. Mertie, Jr., 1940.

DESCRIPTION OF FOSSILS, EXCEPT CIRRIPEDIA

By F. S. MacNeil

MOLLUSCA

CYLICHNELLA (BULLINELLA) NUCLEOLA NOMEANA MacNeil, n. subsp.

Plate 10, figure 1.

A single specimen of *Cylichnella* compares most closely with specimens identified as *C. nucleola* (Reeve) by Dall, but differs slightly in shape, the lower part of the whorl being less inflated, making the shell more evenly inflated rather than inflated below the middle. This gives the columella a gently curved appearance rather than a noticably sharper recurving just below the swollen base of the penultimate whorl. The sculpture and apical characters are identical.

Holotype (U. S. Nat. Mus. 499013)measures: height, 3.6 mm.; diameter, 1.9 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

OENOPOTA MERTIEI MacNeil, n. sp.

Plate 10, figures 2, 3

Shell of moderate size for the genus, inflated; nucleus completely eroded on all specimens at hand; aperture moderately wide; canal short; anal sinus very shallow, anal fasciole slightly concave, terminated below by a weak shoulder; siphonal notch shallow; suture very loosely appressed; parietal callus moderately well developed; axial sculpture consisting of moderately strong, well-spaced ribs, of which about eight are visible from an angle, strongest on the shoulder, terminating above about midway across the fasciolar concavity, continuing below nearly to the basal constriction; revolving sculpture consisting of incised lines, very fine and weak on the anal fasciole, coarser and well-defined, frequently wavy, on the face of the whorls, very coarse, irregular, and forming round-topped riblike interspaces in the basal concavity.

Holotype (U. S. Nat. Mus. 499014) measures: height, 10.5 mm., diameter, 5.5 mm.

Oenopota mertiei does not closely resemble any Recent species of *Oenopota*. It is easily distinguished from *O. harpa* Dall, a circumboreal species, by its more widely spaced axials, which do not reach the suture above, and in having the strong basal radials more sharply set off and restricted to a narrower band. In some respects *O. mertiei* more closely resembles some species of *Propebela*, but no species of the latter have been seen that develop coarse revolving lines in the basal concavity.

Occurrence.—Inner Submarine Beach, locality 14865 (type); Intermediate Beach, 7477?

PROPEBELA aff. P. POPOVIA (Dall)
Plate 10, figure 4

A single incomplete specimen appears to be closely related to *Propebela popovia* (Dall) from Bering Sea. It differs slightly from the Recent species in having a weaker shoulder, so that it may not be specifically identical. The apertural side is broken.

Figured specimen (U. S. Nat. Mus. 499015) measures: height, 6.8 mm.; diameter, 2.9 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

PROPEBELA? sp. indet.
Plate 10, figure 5

A poorly preserved shell so identified from the Inner Submarine Beach may really be an *Oenopota*. It is characterized by closely spaced axial ribs and compares in this respect with several undescribed species from Bering Sea in the National Museum collections. The apertural side is too badly corroded for figuring.

Figured specimen (U. S. Nat. Mus. 499016) measures: height, 8.6 mm.; diameter, 4.4 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

ADMETE COUTHOUYI (Jay)
Plate 10, figures 7–10

Specimens so identified are all from the Inner Submarine Beach and cannot be distinguished from the Recent circumboreal species.

Largest figured specimen (U. S. Nat. Mus. 499017) measures 20.3 mm. in height. Other figured specimens, U. S. Nat. Mus. 499018–20.

Occurrence.—Inner Submarine Beach, locality 14865; Intermediate Beach, 14866.

ADMETE MIDDENDORFFIANA Dall
Plate 10, figure 12

One juvenile specimen resembles Recent specimens of like size from Bering Sea and the Arctic coast.

Figured specimen (U. S. Nat. Mus. 499021) measures: height, 4.2 mm.; diameter, 2.8 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

MOHNIA MOFFITI MacNeil n. sp.
Plate 10, figure 11, ?6

Shell moderately slender and of less than average size for the genus; whorls well-rounded, suture impressed; nucleus unknown; aperture of moderate width; canal short and twisted; columella subtruncate; no anal sinus or fasciole developed; siphonal notch shallow; axial sculpture consisting of moderately strong ribs, rather closely set, 9 to 10 visible from an angle, extending from the suture above to the suture below on the young whorls, becoming obsolete just above the suture on the penultimate whorl and dying out altogether on the last half turn of the body whorl; spiral sculpture consisting of incised lines, stronger and more regular on the juvenile whorls, weak and wavy on the face of the body whorl but stronger in the basal concavity.

Holotype (U. S. Nat. Mus. 499022) measures: height, 13.8 mm.; diameter, 6.2 mm. Doubtful specimen (fig. 6), U. S. Nat. Mus. 499023.

The Recent *Mohnia robusta* Dall from the Pribilof Islands is considerably larger, has a longer, straighter canal; in individuals of the size of the type of *M. moffiti* the axials are stronger, although they become obsolete in larger shells. *Mohnia frielei* Dall from the Queen Charlotte Islands, British Columbia, is of more nearly the same size as *M. moffiti* but is more inflated, has a longer, straighter canal with a less truncate columella, and has a less sharply incised spiral sculpture.

Occurrence.—Inner Submarine Beach, locality 14865.

PLICIFUSUS (MICROFUSUS) cf. P. BRUNNEUS (Dall)
Plate 10, figures 13, 14

Three specimens from the Inner Submarine Beach, although all less than half grown, appear to be identical with the Recent species, which has been found from Port Clarence, Bering Strait, to Nunivak and the Pribilof Islands.

Largest of the figured specimens (U. S. Nat. Mus. 499024) measures: height, 11.3 mm.; diameter, 5.0 mm. Also figured, U. S. Nat. Mus. 499025.

Occurrence.—Inner Submarine Beach, locality 14865.

COLUS (AULACOFUSUS) SPITZBERGENSIS (Reeve)
Plate 10, figure 15

Two fragmental specimens from the Intermediate Beach appear to be identical with the Recent circumboreal species.

The figured specimen (U. S. Nat. Mus. 499026) is a fragment 22 mm. long, and the larger specimen if complete would measure about 40 mm. in length.

Occurrence.—Intermediate Beach, localities 14866, 4538.

COLUS (LATISIPHO) sp. indet.
Plate 10, figure 16

Two fragments of a large *Latisipho* are present in the Intermediate Beach collection. They compare in sculpture with some of the smoother individuals of *Colus* (*Latisipho*) *jordani* Dall, but the suture may be a trifle more impressed than in that species.

The figured fragment (U. S. Nat. Mus. 499027) measures 39 mm. in length and probably represents an individual more than 60 mm. long.

Occurrence.—Intermediate Beach, locality 14866.

CHRYSODOMUS MESLERI Dall
Plate 10, figures 17, 21

Chrysodomus mesleri DALL, *1920*, U. S. Geol., Survey Prof. Paper 125-C, p. 28, pl. 5, figs. 2, 3.

This species from Nome was believed by Dall to have come from the Second Beach, but according to original collection notes his specimens were from the Intermediate Beach.

A large fragment collected by Mertie from the Intermediate Beach shows somewhat better than the badly worn type the derivation in juveniles of the adult axial varix-like ribs from a strong spiral ridge along the shoulder. Nodes first appear along the spiral ridge and become progressively more elongate as the spiral ridge becomes weaker. On about the fourth whorl the axials are heavy and extend nearly to the base of the shell, as shown on the fragment (fig. 21), whereas the spiral ridge is obsolete or visible only as a crimp between the ribs along the shoulder.

Dall stated that *C. saturus* Martyn was the nearest known ally of this species, but it appears much more closely related to *C. solutus* Hermann (=*heros* Gray), a Recent Arctic Ocean and Bering Sea species, from which it differs in being somewhat less inflated, with the heavy axials developing somewhat earlier. *Chrysodomus saturus* has neither as strong a spiral ridge nor the heavy axial ribs that characterize both *C. mesleri* and *C. solutus*.

Figure 17 is of a fragment (U. S. Nat. Mus. 499028) 37.5 mm. in height and 35.0 mm. in diameter. The smaller fragment, 324412, was figured by Dall.

Occurrence.—Intermediate Beach, localities 7619 (type), 5074, 14866.

CHRYSODOMUS sp., fragments
Plate 10, figures 18, 19

Two large columellar fragments of *Chrysodomus* are characterized by spiral sculpture predominating over heavy axial sculpture, as in *C. mesleri* (fig. 21). A specimen known to have come from the Intermediate Beach has spirals of much greater strength than a specimen from an indefinite locality but believed to have come from either the Intermediate or Submarine Beach, and it is not known whether they are distinct species or merely varieties of the same species. *Chrysodomus liratus* Martyn may be related.

The figured specimen from the Intermediate Beach, locality 14866 (U. S. Nat. Mus. 499029), is a fragment 36 mm. long. The other fragment, from locality 9253 (U. S. Nat. Mus. 333047), is 43 mm. long.

CHRYSODOMUS sp., juvenile
Plate 10, figure 20

Both the Mertie collection from the Intermediate Beach and the Otto Halla collection from a "Buried Pliocene Beach," believed to be either the Intermediate Beach or one of the submarine beaches, contain juveniles of a *Chrysodomus* resembling juveniles of one of the smoother varieties of *C. saturus* Martyn, but the identification is uncertain. These specimens have no suggestion of the strong revolving shoulder spiral characteristic of *C. mesleri*.

Figured specimen (U. S. Nat. Mus. 499030) measures: height, 25.5 mm.; diameter, 18.8 mm. A specimen in the Halla collection measures: height, 37.0 mm.; diameter, 19.4 mm.

Occurrence.—Intermediate Beach, locality 14866; uncertain horizon, 9250.

BUCCINUM sp. indet.
Plate 10, figure 22

Specimens fragmental and lacking the surface shell layer.

Figured specimen (U. S. Nat. Mus. 499031) measures: height, 18.0 mm.; diameter, 11.3 mm.

Occurrence.—Intermediate Beach, locality 14866: Inner Submarine Beach, 7623, 14865; Second Beach, 5077.

COLUMBELLA (ASTYRIS) ROSACEA SEWARDENSIS MacNeil, n. subsp.
Plate 10, figure 23

This subspecies differs from the recent typical *C. rosacea* in having a distinctly shorter and more twisted canal, with a deeper siphonal notch and more prominent siphonal fasciole. The shell may also be slightly thicker. There is some range in the degree of columellar twist in the Recent species, but no specimens seen are twisted as much as the Pliocene form.

Holotype (U. S. Nat. Mus. 499032) measures: height, 11.0 mm.; diameter, 4.5 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

TROPHON (BOREOTROPHON) BERINGI (Dall)
Plate 10, figures 24, 25

A juvenile shell from the Inner Submarine Beach and a fragment of an adult from the Intermediate Beach cannot be distinguished from the Recent species.

Larger fragment (U. S. Nat. Mus. 499033) measures 23.0 mm.; the juvenile specimen is numbered 499034.

Occurrence.—Inner Submarine Beach locality 14865; Intermediate Beach, 14866.

TROPHON (TROPHONOPSIS) cf. T. TENUISCULPTUS Carpenter
Plate 10, figure 26

A single incomplete specimen resembles some of the more strongly frilled Recent specimens but differs from most specimens seen in having smoother spiral lines. Though it may be subspecifically distinct from the Recent form, it may prove to be more like the type, a fossil from the upper Pliocene or Pleistocene (Santa Barbara zone) of Santa Barbara, Calif.

Figured specimen (U. S. Nat. Mus. 499035) measures: height, 23.5 mm.; diameter, 12.0 mm.

Occurrence.—Intermediate Beach, locality 14866.

THAIS (NUCELLA) NOMEANA Dall
Plate 11, figure 1

Thais (Nucella) nomeana DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 29, pl. 5, fig. 9.

Dall compared this form with *T. lamellosa* Gmelin, but it appears to be more closely related to the Japanese form described as *Purpura freycinetii* var. *alabaster* Pilsbry, from which it differs mainly in being slightly more umbilicated.

The specimens in Dall's hands were all from the Intermediate Beach and not the Second Beach, as he believed.

The specimen figured by Dall is here designated as lectotype, although neither its station nor catalog number were cited with the description. A lot of badly worn shells from station 5074 is labelled "types" and they bear the catalog number 324318, the only number listed with the description. It is construed, however, that an original figured specimen is a syntype and therefore available as lectotype regardless of the fact that certain other specimens are the only specimens mentioned in the text and the only specimens labelled "types."

Lectotype (U. S. Nat. Mus. 324311) measures: height, 61.5 mm.; diameter, 37.0 mm. Figured specimen (499036) measures: height, 52.0 mm., diameter, 34.0 mm.

Occurrence.—Intermediate Beach, localities 7619 (type), 5074, 14866; Inner Submarine Beach, 7621; uncertain horizon, 7622; Second Beach, 3752, ?5078.

EPITONIUM (BOREOSCALA) GREENLANDICUM SMITHI MacNeil, n. subsp.
Plate 11, figure 2

A single incomplete specimen from the Inner Submarine Beach appears to be sufficiently distinct from the Recent circumboreal species, *E. greenlandicum* to warrant a subspecific name. It differs mainly in having a broader and flatter base, with the basal truncation much stronger. The axial varices

are very weak on the base of the Pliocene subspecies, whereas in the Recent form they frequently continue to the umbilicus with little interruption.

Holotype (U. S. Nat. Mus. 499037) measures: height, 14.6 mm.; diameter, 8.0 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

MELANELLA sp.
Plate 11, figure 7

Two partial specimens of a small unidentified *Melanella* are in the Mertie collection from the Inner Submarine Beach.

Figured specimen (U. S. Nat. Mus. 499038) measures: height, 2.9 mm.; diameter, 1.4 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

TRICHOTROPIS INSIGNIS Middendorff
Plate 11, figures 4, 8

Somewhat worn specimens of this species are present in three collections from the Intermediate Beach. The figured specimens are both from the Mertie collection.

The Recent range of this species is from Bering Strait south, on the west to northern Japan and on the east to the Aleutian Islands and Cooks Inlet, Alaska.

Larger of the figured specimens (U. S. Nat. Mus. 499039) measures: height 19.7 mm.; diameter, 18.1 mm. Smaller figured specimen, 499040.

Occurrence.—Intermediate Beach, localities 5074, 7619, 14866; Second Beach, 5077.

TRICHOTROPIS BICARINATUS (Sowerby)
Plate 11, figure 3

The Mertie collection from the Intermediate Beach contains the first specimens of this species to be recorded from the Nome Beaches. It has been found in the Recent from Point Barrow on the Arctic Coast south, on the west to the Okhotsk Sea and Shantar Islands, and on the east to Nunivak Island, Bering Sea.

Figured specimen (U. S. Nat. Mus. 499041) measures: height, 22.8 mm.; diameter, 17.9 mm.

Occurrence.—Inner Submarine Beach, locality 14865; Intermediate Beach, 14866.

ODOSTOMIA (IOLAEA) AMIANTOPSIS MacNeil, n. sp.
Plate 11, figure 6

Shell small, inflated; nucleus small, unsculptured, consisting of only one turn, the beginning of which has the appearance of rising out of the center of the spire; aperture moderately wide and subovate, slightly over half the height of the shell; no well-defined canal; anal sinus not developed; anal fasciolar area flat; suture weakly appressed; parietal callus very thin; inner lip thin and detached, forming a narrow umbilical slit; sculpture consisting of strong, raised, rounded spiral becoming much weaker on the base, and with a narrow unsculptured strip adjoining the umbilical slit; the three spirals just below the sutural slope the strongest, with a wider space, usually bearing a weak secondary between the first and second spirals.

Holotype (U. S. Nat. Mus. 499042) measures: height, 3.4 mm.; diameter, 2.0 mm.

The nearest known relative of this species is *Odostomia* (*Iolaea*) *amianta* Dall and Bartsch from southern and Lower California. The southern species differs in being less inflated, with thinner and more widely separated spirals, and in having fine, raised growth lines.

Occurrence.—Inner Submarine Beach, locality 14865.

TACHYRHYNCHUS EROSUS MAJOR Dall
Plate 11, figures 5, 9

Several juvenile specimens (fig. 5) of this species are at hand from the Inner Submarine Beach and one large worn fragment (fig. 9) from the Intermediate Beach.

Figured juvenile specimen (U. S. Nat. Mus. 499043) measures: height, 12.2 mm.; diameter, 5.2 mm. The largest fragment (499044) is 19.9 mm. in diameter, exceeding by over 2 mm. the diameter of any Recent specimen in the National Museum collection.

Occurrence.—Inner Submarine Beach, locality 14865; Intermediate Beach, 14866.

TACHYRHYNCHUS LACTEOLUS NOMENSIS MacNeil, n. subsp.
Plate 11, figures 10, 11

This subspecies differs from typical *T. lacteolus* in having weaker spiral lines, thus

making the axial ribs entire and relatively smooth rather than interrupted or beaded. The axials are considerably stronger than in the more southern Recent form, *T. lacteolus subplanatus* (Carpenter).

Holotype (U. S. Nat. Mus. 499045) measures: height, 9.0 mm.; diameter, 3.4 mm. A larger paratype (499046), measures: height, 11.4 mm.; diameter, 4.0 mm.

Occurrence.—Inner Submarine Beach locality 14865 (type); Intermediate Beach, 7477.

LITTORINA PALLIATA (Say)
Plate 11, figure 13

The specimen shown here is that figured by Dall (1920, p. 29, pl. 5, fig. 12) about which he remarked:

> This species is of the type of *Littorina palliata* Say, of which no living form now inhabits the Pacific Ocean or any part of the Arctic coast west of Mackenzie River and east of the Lena. The specimen retains some of the yellowish coloration characteristic of the Atlantic form, and after a scrutinizing comparison with specimens of *Littorina palliata* from Rhode Island and with all the varieties of *obtusata* from Europe, no characters have been discovered by which the Nome fossil can be distinguished from *Littorina palliata*. This is natural enough, as *obtusata* has never been found in America, whereas *palliata* is excessively common on the New England coast in localities where it has not been supplanted by the introduced *Littorina litorea*. The differences of size, form, and geographic distribution seem to be conclusive as to the specific distinction between *Littorina obtusata* and *Littorina palliata*. They are not Arctic shells.

Figured specimen (U. S. Nat. Mus. 324319) measures: height, 12.1 mm.; diameter, 12.2 mm.

Occurrence.—Second Beach, localities 3752, 5078.

LITTORINA (ALGARODA) aff. L. SQUALIDA Broderip and Sowerby

Badly worn fragments of a large *Littorina* related to, if not identical with, the Recent *L. squalida* of the same region are in two collections from the Second Beach.

One specimen has a measurable diameter of 21.5 mm.

Occurrence.—Second Beach, localities 3752, 5078.

NATICA (CRYPTONATICA) aff. N. JANTHOSTOMA Deshayes
Plate 11, figures 12, 14

Many specimens from the Intermediate Beach resemble in shape and semicircular funicle plain-operculate specimens from Japan believed to represent the typical form of *Natica janthostoma* Deshayes, which, according to Deshayes, has a plain operculum. Other specimens from Japan, also labeled *Natica janthostoma*, have a narrower, more elongate funicle and an operculum bearing two deep grooves around the edge. Although no opercula of the species from Nome are at hand, its funicle is more like that of the typical form. The Alaskan shells attained only two-thirds the size of those from Japan.

Largest of the figured specimens (U. S. Nat. Mus. 499047) measures: height, 29.0 mm.; diameter, 26.5 mm. Other figured specimen, 499048.

Occurrence.—Intermediate Beach, localities 14866. 4538, 5074, 7619.

NATICA sp. indet.

Worn and juvenile specimens of a small *Natica* with a low spire, a large aperture, and a callus that completely closes the umbilicus are in the Mertie collection from the Inner Submarine Beach (14865) and a single specimen of what may be the same species is from the Intermediate Beach (14866).

EXPLANATION OF PLATE 12

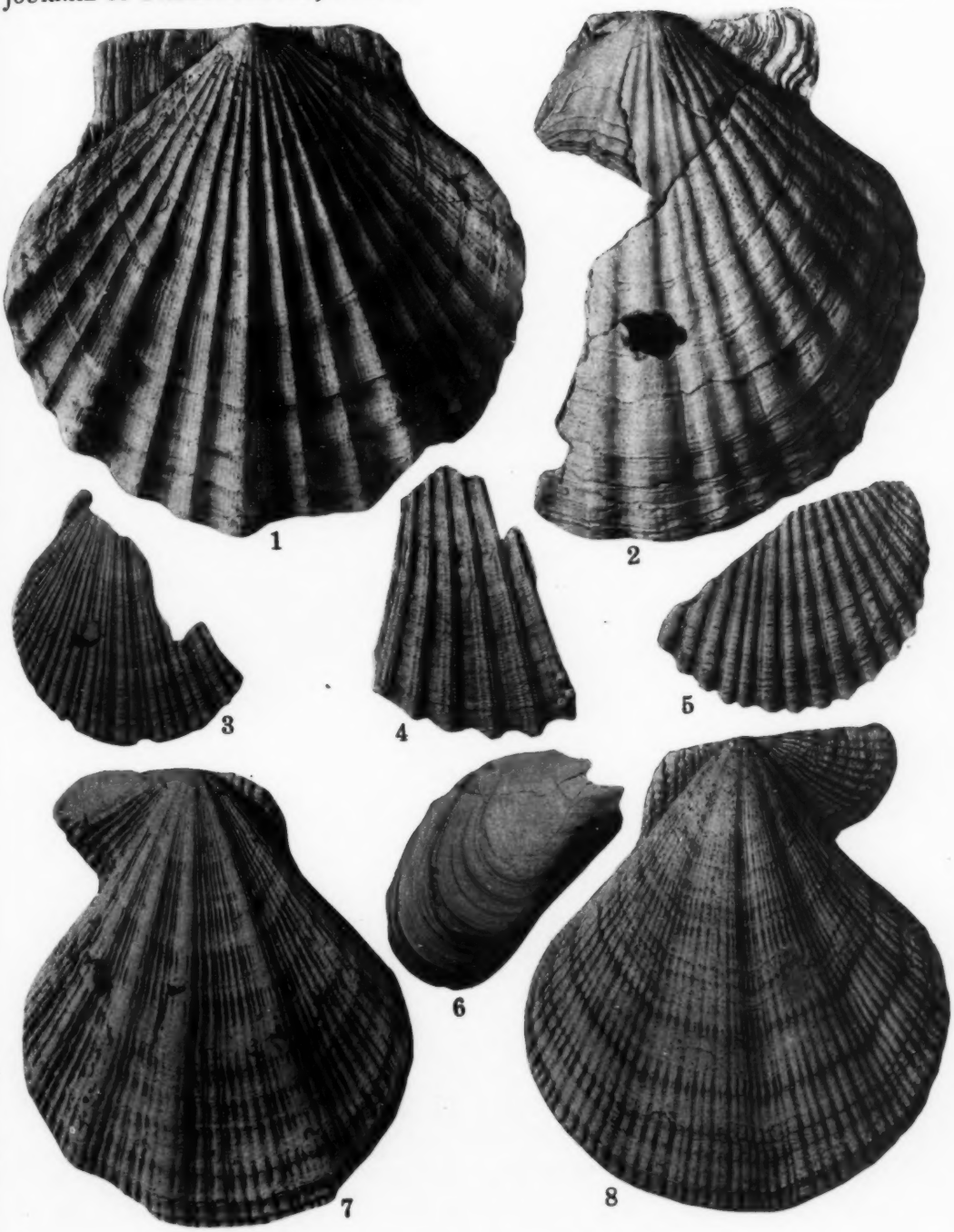
FIGS. *1, 2*—*Pecten* (*Fortipecten*) *hallae* Dall. Horizon uncertain, locality 9250, ×2/3; *1*, a left valve, U. S. Nat. Mus. 499061; *2*, a partial right valve, 499060. (p. 86)

3—*Pecten* (*Chlamys*) *islandicus* Müller. Second Beach, locality 5078a, U. S. Nat. Mus. 324361, ×1. (p. 86)

4, 5—Unidentified fragments of *Pecten*, ×1, Intermediate Beach; *4*, locality 7477, U. S. Nat. Mus. 352618; *5*, locality 14866, U. S. Nat. Mus. 499056. (p. 86)

6—*Mytilus* (*Mytilus*) *edulis* Linnaeus. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499065, ×1½. (p. 88)

7, 8—*Pecten* (*Manupecten*) *kindlei* Dall. Intermediate Beach; *7*, a left valve, ×¾, locality 7619, U. S. Nat. Mus. 499058; *8*, a right valve, ×¾, locality 5313, U. S. Nat. Mus. 499057. (p. 87)



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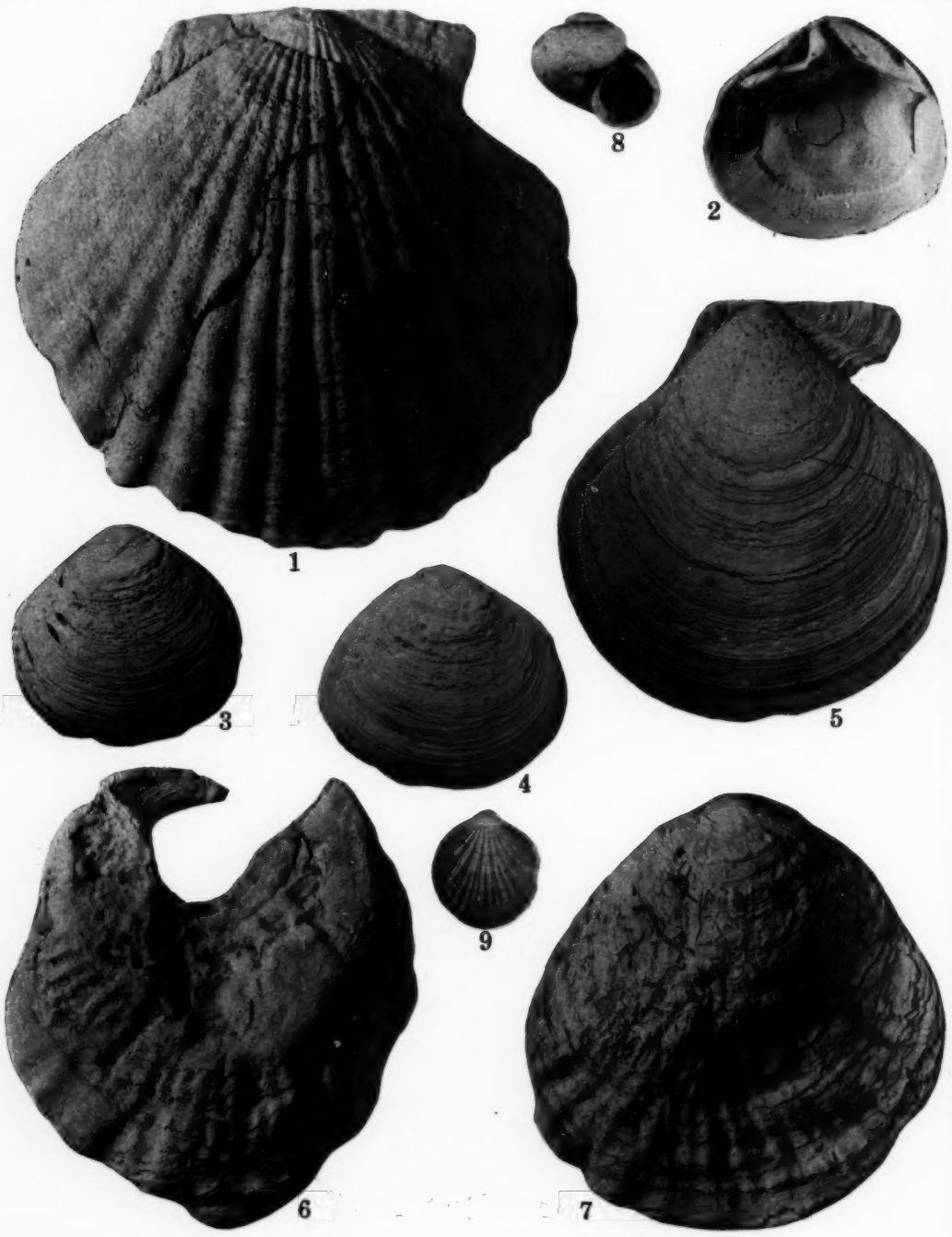


MacNeil, Mertie, and Pilsbry, Fossils from Nome Beaches

LEPETA (CRYPTOCTENIDIA) MAGNA Dall
Plate 11, figure 15.

Cryptoctenidia magna DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 30, pl. 5, fig. 1.

This species, described from the Nome beaches, was believed by Dall to occur only on the Second Beach, but actually his type and all specimens examined by him, except one specimen (numbered 5078, which may be an error), are from the Intermediate Beach. Two specimens are listed under catalog number 324321 as being from station 5078, a locality on the Second Beach, but one of the specimens so numbered bears the station number 7619, an Intermediate Beach number.

Dall's figured specimen (U. S. Nat. Mus. 324320) is here designated the lectotype. The specimen here figured is from the Mertie collection and shows the details of sculpture much better than the lectotype.

Figured specimen (U. S. Nat. Mus. 499049) measures: length, 28.1 mm.; width, 22.8; height, 9.2 mm. The largest fragment measured has a length of 33.0 mm.

Occurrence.—Intermediate Beach, localities 5074 (type), 5313, 7619, 14866; Second? Beach, 5078.

SOLARIELLA (MACHAEROPLAX) VARICOSA NOMEANA MacNeil, n. subsp.
Plate 11, figures 16, 17

This form from the Inner Submarine Beach is closely related to the Recent *S. varicosa* Mighels and Adams of the Atlantic, Pacific, and Arctic coasts of North America. It differs from the typical form in having weaker axials on the body whorl and base, in having a slightly more angular basal truncation or periphery, and, except for two threads along the basal truncation that are stronger than on the typical form, in having consistently weaker spiral lines on the face and base of the body whorl.

Holotype (U. S. Nat. Mus. 499050) measures: height, 5.4 mm.; diameter, 5.7 mm. Paratype, 499062.

Occurrence.—Inner Submarine Beach, locality 14865.

CYCLOSTREMA n. sp.?
Plate 11, figures 21, 22

A fragment of a *Cyclostrema* from the Inner Submarine Beach is related to *C. parva* C. B. Adams but differs in being larger and in having a more nearly closed umbilicus. The sculpture is very similar. Only the body whorl is present on the Nome specimen, and the height of the spire cannot be determined. Several species of *Cyclostrema* of this type are now living off southern California, Mexico, and Panama, but not farther north.

Figured specimen (U. S. Nat. Mus. 499051) measures 2.1 mm. in diameter.

Occurrence.—Inner Submarine Beach, locality 14865.

MÖLLERIA n. sp.?
Plate 13, figure 8

A single somewhat eroded specimen from the Inner Submarine Beach is closely related to *M. quadrae* Dall but differs in being larger than any specimens of that species in the National Museum. Its umbilicus is slightly narrower than in the Recent species.

Figured specimen (U. S. Nat. Mus. 499052) measures: height, 2.9 mm.; diameter, 3.3 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

EXPLANATION OF PLATE 13

FIG. *1—Pecten (Fortipecten) hallae* Dall. Lectotype, ×¾, horizon uncertain, locality 9250, U. S. Nat. Mus. 499059. (p. 86)

2–4—Astarte actis Dall. Intermediate Beach, ×1; *2*, *4*, lectotype, a right valve, locality 5074, U. S. Nat. Mus. 499066; *3*, a left valve, locality 14866, U. S. Nat. Mus. 499067. (p. 88)

5—Pecten (Chlamys) lioicus Dall. Holotype, ×1, "50 feet in Pliocene gravel near Nome, Alaska," locality 4537, U. S. Nat. Mus. 110480. (p. 87)

6, 7—Pododesmus (Monia) macroschisma (Deshayes). Second Beach, locality 7618, ×1; *6*, U. S. Nat. Mus. 499063; *7*, 499064. (p. 87)

8—Mölleria, n. sp.? Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499052, ×6. (p. 85)

9—Crenella nomeana MacNeil, n. sp. Holotype, a right valve, ×8, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499068. (p. 88)

BUCCINUM? sp.
Plate 11, figure 18

A small, probably immature, form has not been definitely identified. Nothing closely resembling it has been found in the National Museum, but insufficient material is at hand to describe it adequately. It may prove to be a turrid.

Figured specimen (U. S. Nat. Mus. 499053) measures: height, 6.0 mm.; diameter, 2.9 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

YOLDIA (YOLDIELLA) SILIQUA (Reeve)
Plate 11, figures 19, 20

A juvenile specimen from the Intermediate Beach has the microsculpture characteristic of the Recent *Y. siliqua*, which occurs in the Atlantic and in Norton Sound, Alaska.

Figured specimen (U. S. Nat. Mus. 499054) measures: length, 3.0 mm.; height, 1.9 mm.

Occurrence.—Intermediate Beach, locality 14866.

PECTEN (CHLAMYS) ISLANDICUS Müller
Plate 11, figure 23; plate 12, figure 3

Specimens from the Intermediate Beach and one fragment in lot 5078a, believed to be from the Second Beach, can be matched with specimens of the variable Recent species.

The largest specimen (pl. 11, fig. 23, U. S. Nat. Mus. 499055) measures 61.0 mm. in height. The fragment figured (pl. 12, fig. 3) is U. S. Nat. Mus. 324361.

Occurrence.—Intermediate Beach, localities 4538, 7477; Third Beach, 5076; ?Second Beach, 5078a.

PECTEN spp.
Plate 12, figures 4, 5

Fragments of two unidentified species of *Pecten* are present in collections from the Intermediate Beach. Both may be new. One of the fragments (fig. 4) was listed by Dall as "*Pecten* (*Chlamys*), n. sp. (fragment). Southern type." The surface of this shell bears a microsculpture similar to that of *P. islandicus*, but the ribbing cannot be matched in that species.

The specimen shown in figure 4 is numbered U. S. Nat. Mus. 352618; figure 5, 499056.

Occurrence.—Intermediate Beach (species represented by fig. 4) localities 7477, 14866; (species represented by fig. 5) 14866.

Subgenus FORTIPECTEN Yabe and Hatai

Pecten (*Fortipecten*) YABE and HATAI, *1940*, Tohoku Imp. Univ. Science Reports, Geology, vol. 21, no. 2, p. 149.

PECTEN (FORTIPECTEN) HALLAE Dall
Plate 12, figures 1, 2; Plate 13, figure 1

Pecten (*Plagioctenium*) *hallae* DALL, *1921*, Nautilus, vol. 34, p. 76.

Pecten (*Patinopecten*) *rhytidus* DALL, *1921*, *idem*, p. 77.

Pecten (*Aequipecten*) *hallae*, GRANT and GALE, *1931*, San Diego Soc. Nat. Hist. Mem., vol. 1, p. 220.

Pecten (*?Vertipecten*) *rhytidus*, GRANT and GALE, *1931*, *idem.*, p. 191.

The two valves of this species, which were described not only as different species but were placed in different subgenera, have never been figured. Consequently Grant and Gale, who had only the descriptions to go by, were misled as to the identity of the forms and placed them in two other different subgenera.

Pecten hallae is closely related to the type of the subgenus *Fortipecten* Yabe and Hatai, *Pecten takahashii* Yokoyama (1940, p. 149, pl. 34, figs. 1–9, pl. 35, figs. 1–9.) from the lower and middle Pliocene of Japan, and together they comprise the known species of *Fortipecten*.

The Alaskan species differs from the Japanese species in being slightly less inflated and in having broader ribs, those of the right valve of *P. hallae* being wider than the interspaces, whereas in *P. takahashii* the ribs of the right valve are definitely narrower than the interspaces. Less contrast exists between the width of the ribs on the left valves. In spite of the differences pointed out, however, the similarity of the two forms is striking. Both are very heavy shells with large adductor scars.

Dall in his description of *P. hallae* and *P. rhytidus* stated that no microsculpture is visible, but of two left valves (*rhytidus*) labelled "type," the smaller and better preserved specimen retains in spots a fine sculpture in which successive lamellae are

crinkled, with the crinkles of adjacent rows offset, the whole resembling the surface of metal plaster lath. This specimen is here figured, although the larger labelled specimen, the specimen whose dimensions were given in the original description, should probably be regarded as the type of *rhytidus*.

Pecten takhashii has been determined by Japanese geologists to occur in beds believed to be lower and middle Pliocene. It is not apparent at present whether the species difference between the Alaskan and Japanese species is mainly a function of geographic separation or of actual time difference, but it is doubtful if the oldest of the beaches are as old as lower Pliocene. Probably all are late Pliocene, with a possibility that the youngest is early Pleistocene.

Lectotype (a right valve, the labelled type of *P. hallae* Dall, U. S. Nat. Mus. 499059) measures: height, 120.0 mm.; width, 126.0 mm.; convexity, 28.0 mm. The largest specimen, an incomplete valve, has a width of more than 145 mm. Figured paratypes are U. S. Nat. Mus. 499060, 499061. The original number 333042 assigned to all the type material of *P. hallae* now refers only to right valve paratypes exclusive of the figured paratypes. Left valve paratypes (*P. rhytidus*), exclusive of the figured paratype, bear the number 333044.

Occurrence.—"Buried Pliocene beach, 20 feet below surface, near Solomon River. Collector, Otto Halla." The exact beach is not known, but according to Doctor P. S. Smith, Chief Alaskan Geologist of the Geological Survey, Otto Halla was a mining man who operated mainly near Nome on the Submarine Beaches. Locality 9250.

PECTEN (MANUPECTEN) KINDLEI Dall
Plate 12, figures 7, 8

Pecten swifti Bernhardi. DALL, *1907*, Am. Jour. Sci., vol. 173, p. 457.
Pecten (Chlamys) kindlei DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 30, pl. 6, figs 2, 7.
Pecten (Pallium) swifti kindlei, GRANT and GALE, *1931*, San Diego Soc. Nat. History Mem., vol. 1, p. 174, pl. 10, fig. 7.

Little can be added to Dall's discussion concerning this species. As pointed out by Dall, the relationships of this species are with *P. swifti* Bernardi of the Pliocene to Recent of Japan, and with *P. parmeleei* Dall, a closely related species from the Pliocene of California. It differs from either of these, however, in lacking the large wavy nodes and resting stages characteristic of both.

Figured specimens: Right valve (U. S. Nat. Mus. 499057) measures: height, 106.0 mm.; width, 93.5 mm.; convexity 13.0 mm. Left valve (499058) measures: height, 92.0 mm.; width, 77.0 mm.; convexity, 17.0 mm.

Occurrence.—Intermediate Beach, locality 7619 (type), 4538, 5074, 5313, 14866; Second Beach, 7618? (fragment).

PECTEN (CHLAMYS) LIOICUS Dall
Plate 13, figure 5

Pecten (Chlamys) lioicus DALL, *1907*, Am. Jour. Sci., ser. 4, vol. 23, p. 457, text fig.
Pecten (Chlamys) lioicus, DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 31.
Pecten (Pecten) lioicus, GRANT and GALE, *1931*, San Diego Soc. Nat. History Mem., vol. 1, p. 165.

Grant and Gale suggested that this form may be a monstrosity of *P. islandicus*, and this may indeed be the case. It resembles *P. islandicus* in all respects except that the ribs are only feebly developed.

Holotype (U. S. Nat. Mus. 110480) measures: height, 61 mm.; width, 57 mm.; convexity, 9.5 mm.

Occurrence.—The type came from "gravels under tundra near Nome, Alaska, at a depth of 50 feet." The exact location and beach are not known. Locality 4537.

PODODESMUS (MONIA) MACROSCHISMA (Deshayes)
Plate 13, figures 6, 7

This common West-Coast *Pododesmus* is widely distributed in the Pliocene, Pleistocene, and Recent. Its Recent range does not extend to Nome, the limit being south of the winter line of floating ice in southern Bering Sea, from the Pribilof Islands south, on the west to Japan and on the east to Lower California and Mexico.

Figured specimens from the Second Beach, locality 7618 (U. S. Nat. Mus. 499063, 499064). The maximum height of the Nome specimens is about 65 mm.

Occurrence.—Intermediate Beach, localities 4538, 5074, 5313, 7619, 14866; Second Beach, 5077, 7618; uncertain horizon, 7622.

CRENELLA NOMEANA MacNeil, n. sp.
Plate 13, figure 9

Shell small, little inflated, nearly circular in outline; beaks central, breaking the circular outline only slightly, prodissoconch moderately large; sculpture consisting of low, broad, flat ribs, the median rib nearly straight, the lateral ribs fanning out subsymmetrically, becoming more curved passing outwards, the primary ribs becoming divided and near the margin tending to divide again, new ribs, originating between the primary ribs at about the stage of the first bifurcation, interspaces of about the same size as the ribs, delicate raised growth varices present in the interspaces but not crossing the ribs; inner margin weakly crenulate near the edge.

Holotype (U. S. Nat. Mus. 499068) measures: height, 2.0 mm.; length, 1.9 mm.; convexity, 0.6 mm.

This species is remarkable for its coarse sculpture. It is related to the Recent *C. divaricata* d'Orbigny, which, however, has a more southern range, from the Santa Barbara Islands to Panama Bay. The Recent species differs in being shorter and higher, more inflated, and in having somewhat finer sculpture.

Occurrence.—Inner Submarine Beach, locality 14865.

MYTILUS (MYTILUS) EDULIS Linnaeus
Plate 12, figure 6

No complete valves of this species are in any of the Nome beach collections, but the numerous fragments show no characters to distinguish them from the Recent form.

The figured specimen (U. S. Nat. Mus. 499065) is a fragment 28.0 mm. long.

Occurrence.—Inner Submarine Beach, localities 7621, 14865; uncertain horizon, 7622; Intermediate Beach, 5074, 14866; Second Beach 5078a.

ASTARTE ACTIS Dall
Plate 13, figures 2–4

Astarte actis DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 31, pl. 6, figs. 4, 5.
Astarte actis, GRANT and GALE, *1931*, San Diego Soc. Nat. History Mem., vol. 1, p. 269.

This species closely resembles the Recent *Astarte rollandi* Bernardi, from which it differs mainly in being rounder and somewhat heavier. The variety *A. rollandi loxia* Dall has a more depressed lunule and a lighter hinge. *Astarte rollandi* is now found from the Pribilof and Aleutian Islands to Prince William Sound, Alaska, and Kamchatka.

The name *Astarte actis* first appeared (Dall, 1919, p. 2) as a nude name in a list of fossils from St. George Island of the Pribilof group, but Dall was undoubtedly merely identifying a fossil from that locality with an as yet unpublished form from the Nome beaches.

Dall's figured specimen, here designated the lectotype, bears locality number 5074 and U. S. Nat. Mus. 324302, an error, since all other specimens from station 5074 are numbered 324303. Other specimens numbered 324302 are from station 7619. A new catalog number is here assigned to the lectotype. Furthermore, Dall believed his specimens to have come from the Second Beach,

EXPLANATION OF PLATE 14

FIGS. *1–5—Astarte* (*Rictocyma*) *diversa* Dall. Intermediate Beach, locality 14866, ×1½; *1*, right valve, U. S. Nat. Mus. 499073; *2*, left valve, 499074; *3*, left valve, 499075; *4*, right valve, 499076; *5*, left valve, 499077. (p. 90)

6–8—Astarte hemicymata Dall. Intermediate Beach, locality 14866, ×1; *6*, *8*, exterior and interior of a right valve, U. S. Nat. Mus. 499069; *7*, exterior of a left valve, 499108. (p. 89)

9, *10—Taras* cf. *T. orbellus* (Gould). Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499084, ×8. (p. 91)

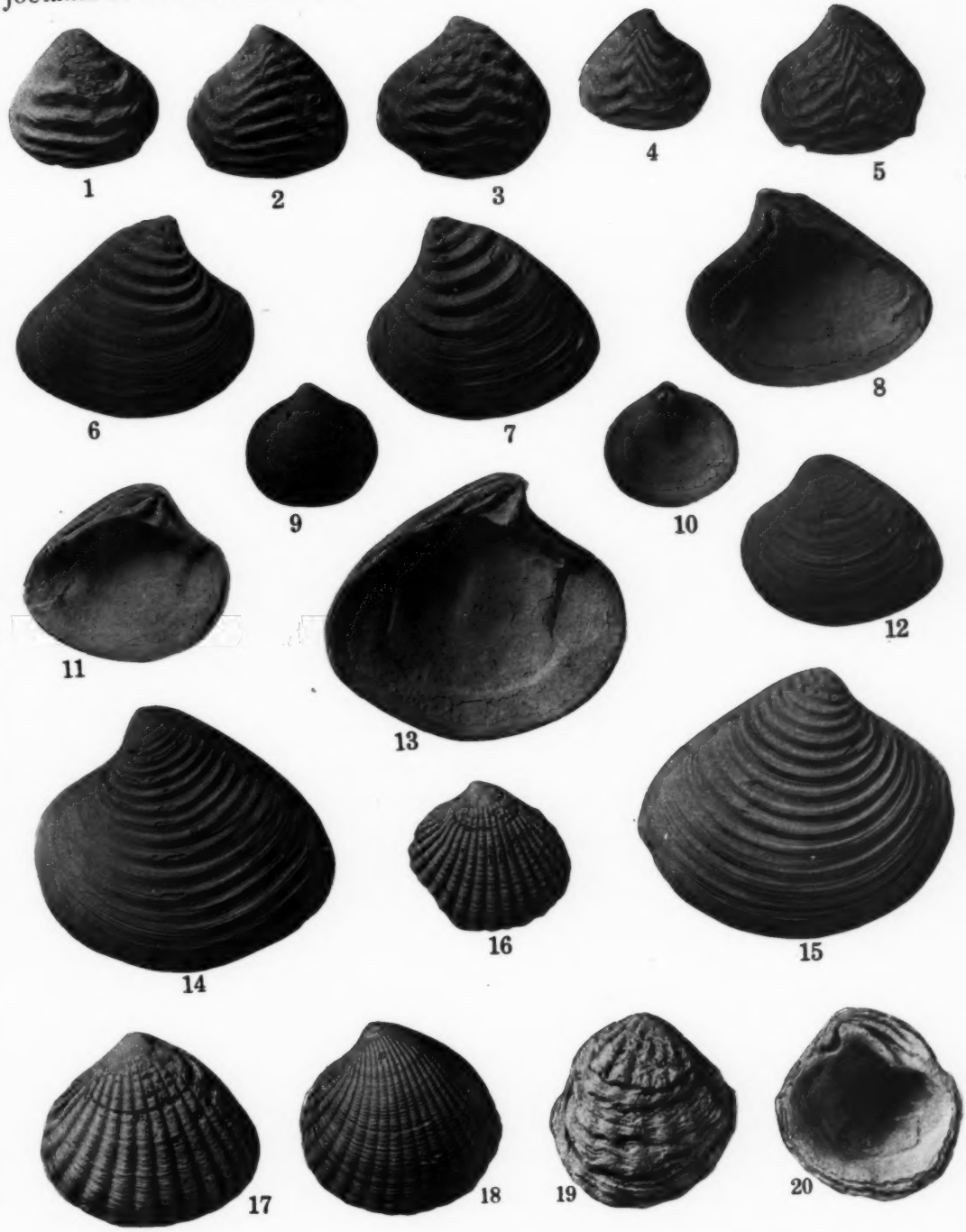
11, *12—Astarte leffingwelli* Dall. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499072, ×1. (p. 89)

13–15—Astarte nortonensis MacNeil, n. sp. Intermediate Beach, locality 14866, ×1; *13*, *14*, holotype, a left valve, U. S. Nat. Mus. 499070; *15*, paratype, a right valve, 499071. (p. 89)

16, *17—Cardita* (*Cyclocardia*) *crebricostata* (Krause). Intermediate Beach, locality 14866; *16*, juvenile left valve, U. S. Nat. Mus. 499078, ×2; *17*, left valve, 499079, ×1. (p. 90)

18—Cardita (*Cyclocardia*) *crebricostata nomensis* MacNeil, n. subsp. Holotype, a left valve, ×1½, Intermediate Beach, locality 4538, U. S. Nat. Mus. 499080. (p. 90)

19, *20—Cardita* (*Cyclocardia*) sp. A right valve, ×4, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499083. (p. 91)



MacNeil, Mertie, and Pilsbry, Fossils from Nome Beaches

UNIV. OF MICH.

whereas the original field notes indicate that all are from the Intermediate Beach.

This is one of the most abundant shells of the Intermediate Beach, judging from the number of specimens in the Mertie collection.

Lectotype (U. S. Nat. Mus. 499066) measures: height, 32.4 mm.; length, 36.4 mm.; convexity, 8.4 mm. The other figured specimen is numbered 499067.

Occurrence.—Intermediate Beach, localities 5074 (type), 5313, 7477?, 7619, 14866; Second Beach, 5078, 7618.

ASTARTE HEMICYMATA Dall
Plate 14, figures 6–8

Astarte hemicymata DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 32, pl. 6, figs. 9, 10.

Astarte hemicymata, GRANT and GALE, *1931*, San Diego Soc. Nat. History Mem., vol. 1, p.269.

This species is closely related to the Recent *A. alaskensis* Dall, from which it differs in being consistently more triangular, with a higher and sharper beak and more sharply rounded anterior and posterior ends.

The type material is fragmental, and the species is here illustrated by more complete valves from the Mertie collection.

Holotype, U. S. Nat. Mus. 324308. Figured specimens, 499069, 499108. The larger measures: height, 30.0 mm.; length, 36.8 mm.; convexity, 7.5 mm.

Occurrence.—Inner Submarine Beach localities 7623 (type), 14865; Intermediate Beach, 7477, 14866.

ASTARTE NORTONENSIS, MacNeil, n. sp.
Plate 14, figures 13–15

Shell moderately large, subovate, flattened, anterior evenly rounded, posterior more sharply rounded; beaks high, moderately narrow, recurving; lunule moderately broad and indented; sculpture consisting of strong concentric undulations extending from the beak to between half and three-quarters the distance to the base of adults and usually from 13 to 18 in number, and finer incremental lines, many of which cross the larger undulations at a very low angle; hinge of moderate strength, compressed and directed somewhat to the posterior; muscle scars moderately impressed; inner margins smooth.

Holotype (U. S. Nat. Mus. 499070) measures: length, 45.2 mm.; height, 39.0 mm.; convexity, 7.5 mm. Paratype, 499071.

This species is most closely related to *A. borealis* Schumacher, but the concentric undulations are much coarser and extend farther down, and the beaks are more pointed, with a deeper lunule. Specimens from Bearing Sea off the Kudobin Islands on the north side of the Alaskan Peninsula (U. S. Nat. Mus. 169578) have undulations of more comparable texture although fewer in number.

Occurrence.—Intermediate Beach localities 14866 (type), 7477; Inner Submarine Beach, 7621?; uncertain horizon, 9250.

ASTARTE LEFFINGWELLI Dall
Plate 14, figures 11, 12

Astarte leffingwelli DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 32, pl. 6, figs. 6, 8.

A single valve in the Mertie collection from the Intermediate Beach is believed to be this species. The Nome specimen has the growth lines shortened near the margin, with the margin thickened, suggesting that it is an individual abnormality. The sculpture of rough concentric incremental lines is identical with that of the type and other specimens from the Arctic coast 15 to 30 miles below Point Barrow.

Figured specimen (U. S. Nat. Mus. 499072) measures: height, 26.0 mm.; length, 30.0 mm.; convexity, 7.1 mm.

Occurence.—Intermediate Beach locality 14866.

ASTARTE aff. A. FABULA Reeve

The fragments so referred to are of a moderately small *Astarte* having fine concentric crenulations that are more sharply defined along their upper margin, slope gently to the next crenulation below, and become obsolete about midway of the shell. *Astarte fabula* was reported by Dall from two stations, 7620 and 7624, which, if the original notes are to be relied upon, are from the Inner Submarine Beach. The specimens in question still retain the periostracum, however, and the writer is inclined to believe they are really Recent specimens. A single poor fragment from the Inner Submarine Beach (locality 14865) in the Mertie collection is questionably referred to the species.

ASTARTE (RICTOCYMA) DIVERSA Dall
Plate 14, figures 1–5

Astarte (Gonilia?) diversa DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 33, pl. 5, fig. 6.

This species is most closely related to *Astarte (Rictocyma) esquimalti* Baird, which is living from Point Barrow on the Arctic Coast south to the Aleutian Islands and Puget Sound. It is quite distinct specifically, however, having much coarser sculpture. The coarse undulations exhibit considerable range in relief and pattern, being very pronounced on some individuals and faint on others, but on all specimens the chevrons are sharper than on any available Recent specimens of *A. esquimalti*. *Astarte diversa* does not appear to be closely related to *Astarte (Gonilia) calliglypta* Dall (=*bipartita* Philippi) from the Mediterranean, as suggested by Dall.

The figured specimens are U. S. Nat. Mus. 499073–499077. Some range in proportions exists. A short, high specimen measures: height, 16.6 mm.; length, 16.5 mm.; convexity, 4.2 mm. A more elongate specimen measures: height, 16.8 mm.; length, 18.4 mm.; convexity, 4.4 mm.

Occurrence.—Inner Submarine Beach, localities 7623 (type), 14865; Intermediate Beach, 7477, 14866.

CARDITA (CYCLOCARDIA) CREBRICOSTATA (Krause)
Plate 14, figures 16, 17

Specimens identified as this species are similar to the more coarsely ribbed Recent specimens referred to it by Dall. It is probable that more than one Recent subspecies exists, but it is impossible without recourse to Krause's type to determine which is the typical form. The types of *Venericardia alaskensis* Dall, which he later placed in synonymy with *C. crebricostata*, have narrower, weaker, and more closely spaced ribs. "*Venericardia crassicostata*," which appears in Dall's list for locality 7623, is an error for *crebricostata*, probably resulting from writing *V. crassidens* in the list for the preceding station.

Figured specimens are U. S. Nat. Mus. 499078 and 499079. The larger, figure 17, measures: height, 29.0 mm.; length, 22.8 mm.; convexity, 8.2 mm.

Occurrence.—Inner Submarine Beach, locality 14865; uncertain horizon, 9250; Intermediate Beach, 5074, 7477, 14866; Second Beach, 3752?

CARDITA (CYCLOCARDIA) CREBRICOSTATA NOMENSIS MacNeil, n. subsp.
Plate 14, figure 18

This subspecific name is proposed for a form reported by Dall from localities 4538 and 7618 as *Venericardia crebricostata*. No other specimens have been recovered. It differs from the form regarded as *C. crebricostata*, s.s., in having 27 or 28 ribs (as compared with 22 to 25), flatter, and more closely set, with shallow, sharp V-shaped interspaces rather than deep, bluntly V-shaped or U-shaped interspaces.

Several lots of specimens from localities along the south side of the Alaskan Peninsula and the Aleutian Chain, and particularly a lot from North East Harbor in the Shumagin Islands (U. S. Nat. Mus. 169725), approach this subspecies in the details of sculpture, but consistently have only 25 or 26 ribs.

Holotype (U. S. Nat. Mus. 499080) measures: height, 18.8 mm.; length, 20.0 mm.; convexity, 4.9 mm. A larger worn specimen in the same lot measures approximately: height, 24 mm.; length, 26 mm.; convexity, 6.0 mm.

Occurrence.—Intermediate Beach, locality 4538 (type); Inner Submarine Beach, 14865; Second Beach, 7618.

CARDITA (CYCLOCARDIA) SUBCRASSIDENS MacNeil, n. sp.
Plate 15, figures 1, 3

Shell moderately large, rounded, thick; valves moderately inflated; juveniles more elongate and subrhomboidal; beaks prominent, well to the anterior; sculpture consisting of 7 to 10 broad, rounded ribs curving from the beaks to the ventral margin, becoming weaker and nearly obsolete below on full-grown specimens; interspaces broad, shallow and rounded; irregular concentric incrementals and very fine scratchlike radials also adorn the surface; muscle scars impressed; inner margin with coarse, shallow crenulations; hinge heavy, with a nearly horizontal aspect.

Holotype (U. S. Nat. Mus. 499081) meas-

ures: height, 33.0 mm.; length, 32.4 mm.; double convexity, 18.3 mm.

This species was reported from the Nome beaches by Dall as typical *C. crassidens* Broderip and Sowerby. It is undoubtedly the forerunner of the Recent species, which inhabits Bering Sea and eastward to Kodiak Island. Specimens of *C. crassidens* in the National Museum have a minimum of 12 ribs, however, with most specimens having 14 or 15. There is also a tendency for the Recent species to be more flattened along the ventral margin, making the outline less rotund than in the fossil species.

Occurrence.—Intermediate Beach, localities 14866 (type), 4538; Inner Submarine Beach, 7621?, 14865; uncertain horizon, 7622; Second Beach, 5078a, 7618.

CARDITA (CYCLOCARDIA) sp.
Plate 14, figures 19, 20

A single small valve of a *Cardita* from the Inner Submarine Beach appears at first sight distinct from the forms listed above. It has very distorted growth lines and is rather more tumid than any of these, suggesting that it may be only an abnormal or pathologic specimen.

The specimen (U. S. Nat. Mus. 499083) measures: height, 7.0 mm.; length, 7.0 mm.; convexity, 3.0 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

TARAS cf. T. ORBELLUS (Gould)
Plate 14, figures 9, 10

A single immature valve of *Taras* has the rounded outline of this Recent species, which has been taken living from the Pribilof Islands south of the Gulf of California, rather than that of the more ovate, posteriorly inflated *T. aleutica* Dall, which inhabits the region from the Arctic Ocean to Sitka Bay, nearer the locality of the fossil.

Figured specimen (U. S. Nat. Mus. 499084) measures: height, 2.3 mm.; length, 2.4 mm.; convexity, 0.6 mm.

Occurrence.—Inner Submarine Beach, locality 14865.

CARDIUM (CERASTODERMA) CILIATUM BROOKSI MacNeil, n. subsp.
Plate 15, figure 14

Decorticated specimens and fragments of a *Cardium* from several stations on the Nome beaches were identified by Dall as *C. ciliatum*. What sculpture remains on the specimens at hand cannot be matched in Recent specimens of *C. ciliatum*, although they appear to be very closely related, and the subspecific name is proposed. The ribs of the Nome form are more numerous, more closely set, and rounded on top rather than angular as in typical *C. ciliatum*, and the interspaces are narrower with much steeper sides.

Holotype (U. S. Nat. Mus. 499085) measures: height, 22 mm. (incomplete); length 31 mm. (probably about 2.0 mm. should be added); convexity, 8.8 mm.

Occurrence.—Intermediate Beach, localities 14866 (type), 4538, 5074, 7477?, 7619; Second Beach, 5078a, 5078, 7618; Inner Submarine Beach, 7621, 7623, 14865; Uncertain horizon, 7622.

SERRIPES GRÖNLANDICUS (Bruguière)

A fragment from the Second Beach is the only record of this species from the Nome beaches. The fragment is of a medium-sized individual and shows little more than the surface sculpture.

Occurrence.—Second Beach, locality 5077.

TELLINA (PERONIDIA) LUTEA Gray
Plate 15, figure 12

A fragment (U. S. Nat. Mus. 499086) from the Intermediate Beach is indistinguishable from the Recent species. It has a length of 40 mm. and probably represents an individual of twice this size.

Occurrence.—Intermediate Beach, locality 14866.

MACOMA MIDDENDORFFI Dall
Plate 15, figures 2, 5

Judging from the number of specimens in the Mertie collection, this is one of the most abundant species on the Intermediate Beach. No morphologic differences are apparent between it and the Recent form, but no specimens in the Nome collections attain the size of the larger Recent specimens.

Figured specimens, U. S. Nat. Mus. 499087 and 499088. The larger measures: height, 43.0 mm.; length, 46.0 mm.; convexity, 11.0 mm. The largest specimen measured has the dimensions: height, 48.8 mm.;

length, 54.3 mm.; convexity, 12.5 mm. A large Recent specimen measures: height, 57.0 mm.; length, 61.2 mm.

Occurrence.—Inner Submarine Beach, locality 7621?; uncertain horizon, 7622; Intermediate Beach, 4538, 5074, 5313, 7619, 14866; Second Beach, 3752, 5078, 7618.

MACOMA INCONGRUA (Martens)
Plate 15, figures 4, 6, 7

Specimens from several localities on different beaches here referred to this species were identified by Dall in part as *M. incongrua* and in part as *M. balthica* Linnaeus. All of the specimens that are well enough preserved for specific identification appear definitely to be *M. incongrua*. Of the worn fragments, some of which were reported as *M. balthica*, none are sufficiently well preserved for accurate determination, but there is no reason to suppose that they are of a different species than the better preserved individuals.

Figured specimens, U. S. Nat. Mus. 499089 and 499090. The larger, a left valve, is 25 mm. in height and 5.5 mm. in convexity, length not entire but probably about 31 mm.

Occurrence.—Uncertain horizon, locality 7622; Intermediate Beach, 4538, 5074, 7619; Second Beach, 5078, 7618.

MACOMA CALCAREA (Gmelin)
Plate 15, figure 19

One incomplete valve from the Intermediate Beach is indistinguishable from the Recent species.

Figured specimen (U. S. Nat. Mus. 352614) is 26.8 mm. long.

Occurrence.—Intermediate Beach, locality 7477: Inner Submarine Beach, 7623?.

SILIQUA aff. S. "MEDIA Gray" Dall
Plate 15, figures 15, 18

According to Grant and Gale (1931, p. 388), *S. media* is a synonym of *S. alta* (Broderip and Sowerby), and the name *media* itself should be attributed to G. B. Sowerby and not to Gray.

Two fragments of a *Siliqua*, one identified by Dall as *S.* cf. *S. patula* (Dixon), and an additional fragment in the Mertie collection are at hand. The moderately heavy, nearly vertical internal rib and rough, irregular corrugations just behind the internal rib in the umbonal cavity suggest that this form is more closely related to *S. media* than to *S. patula*.

Figured specimen (U. S. Nat. Mus. 499091) is a fragment measuring: height, 18.8 mm.; length (partial) 33.2 mm.

Occurrence.—Intermediate Beach, localities 5074, 14866.

EXPLANATION OF PLATE 15

FIGS. *1, 3*—*Cardita* (*Cyclocardia*) *subcrassidens* MacNeil, n. sp. Holotype, ×1, Intermediate Beach, locality 14866, U. S. Nat. Mus. 499081; *1*, exterior of left valve; *2*, interior of right valve. (p. 90)

2, 5—*Macoma middendorffi* Dall. Intermediate Beach, locality 14866, ×1; *2*, left valve, U. S. Nat. Mus. 499087; *5*, right valve, 499088. (p. 91)

4, 6, 7—*Macoma incongrua* (Martens). Second Beach, locality 7618, ×1; *4*, left valve, U. S. Nat. Mus. 499089; *6, 7*, right valves, U. S. Nat. Mus. 499090. (p. 92)

8, 9—*Verruca alaskana* Pilsbry, n. sp. ×6, Intermediate Beach, locality 14866, U. S. Nat. Mus. 499109. (p. 95)

10—*Balanus rostratus alaskensis* Pilsbry. Interior, ×1, Intermediate Beach, locality 14866, U. S. Nat. Mus. 499107. (p. 94)

11, 13—*Saxicava pholadis* (Linnaeus). Second Beach, locality 3752, U. S. Nat. Mus. 499096, ×1½; *11*, exterior; *13*, interior. (p. 94)

12—*Tellina* (*Peronidia*) *lutea* Gray. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499086, ×1. (p. 91)

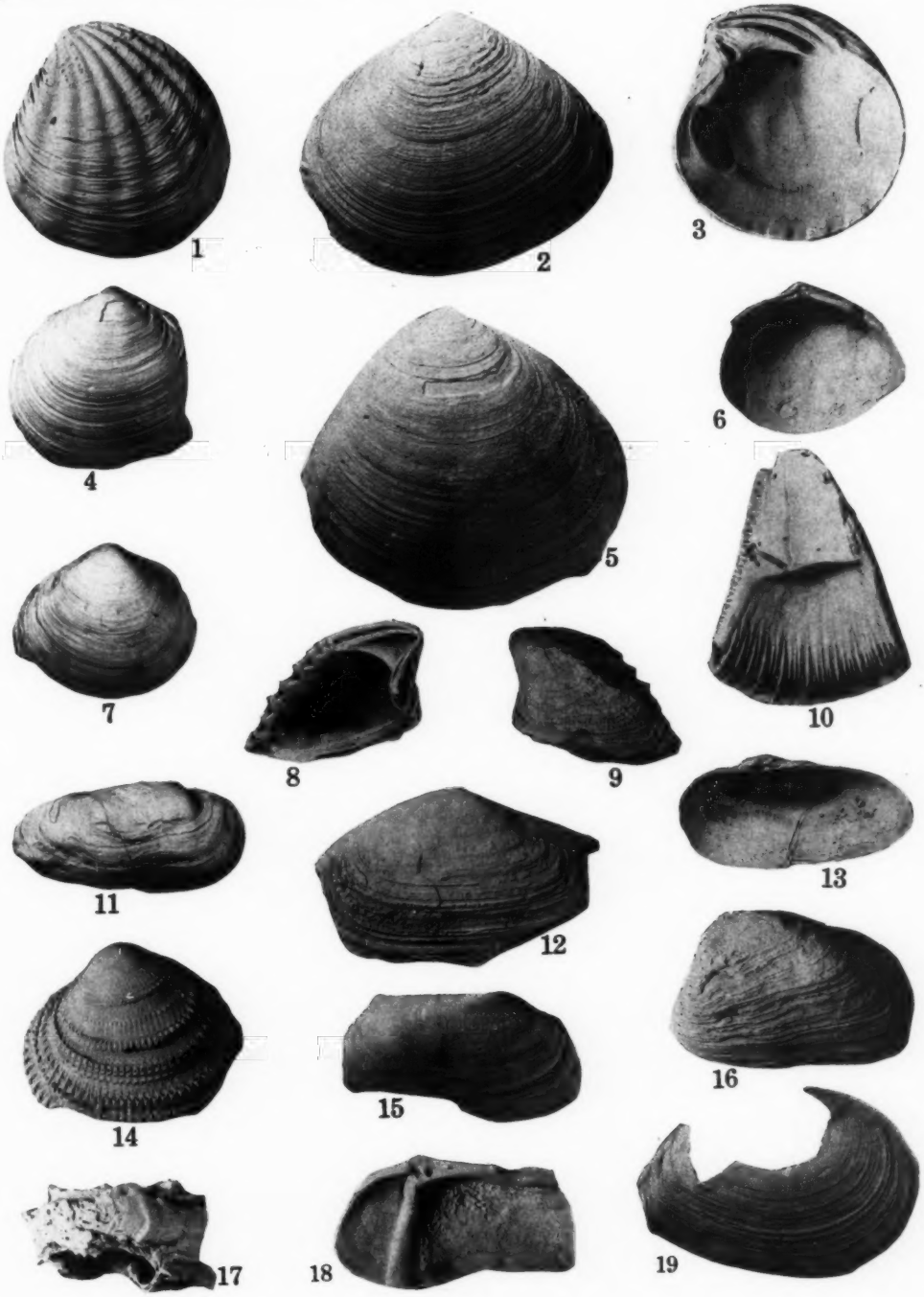
14—*Cardium* (*Cerastoderma*) *ciliatum brooksi* MacNeil, n. subsp. Holotype, ×1, Intermediate Beach, locality, 14866, U. S. Nat Mus. 499085. (p. 91)

15, 18—*Siliqua* aff. *S. "media* Gray" Dall. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499091, ×1; *15*, exterior of a right valve; *18*, interior of same. (p. 92)

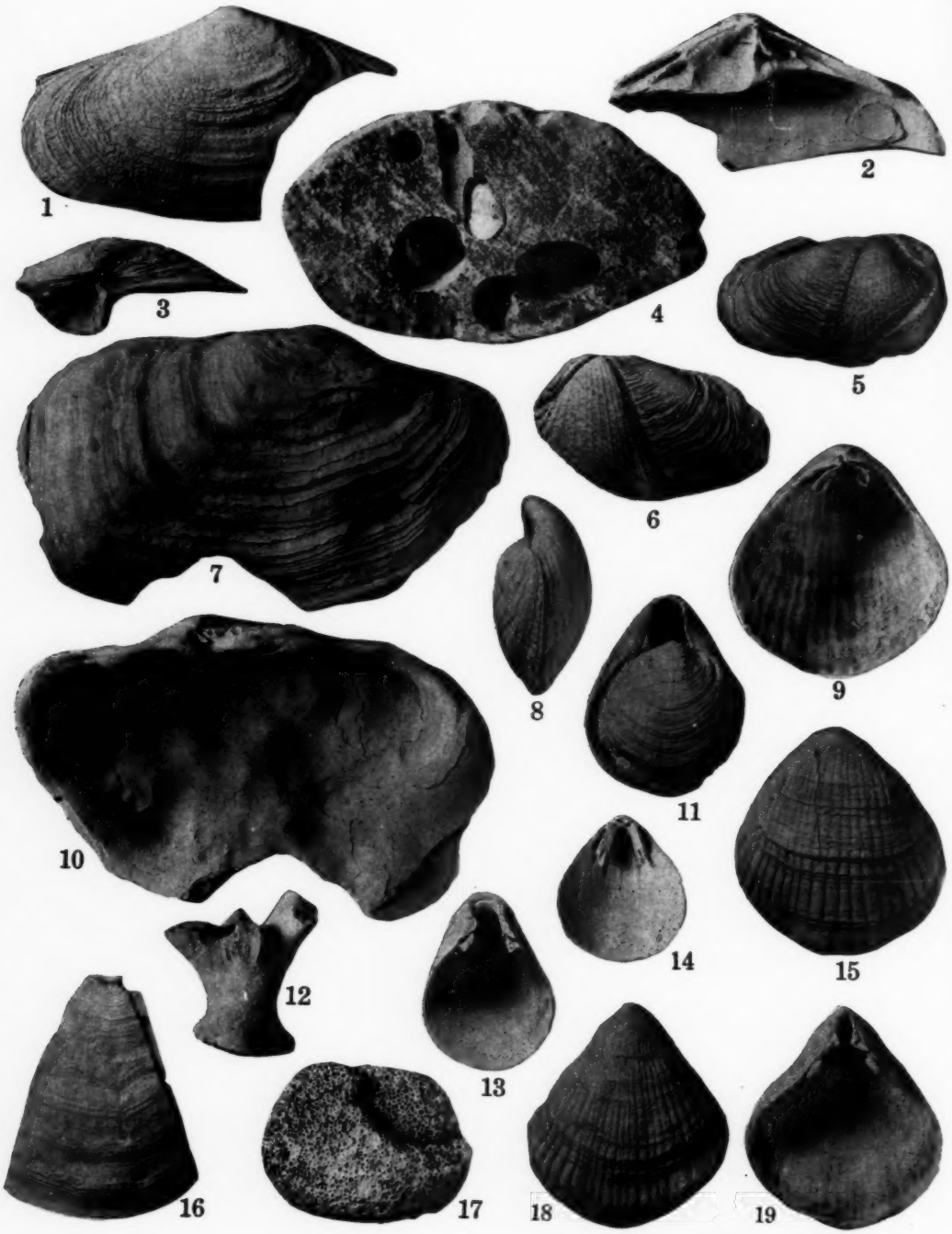
16—*Saxicava arctica* (Linnaeus). Intermediate Beach, locality 14866, U. S. Nat. Mus. 499095, ×1½. (p. 93)

17—*Serpula?* sp. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499104, ×1. (p. 94)

19—*Macoma calcarea* (Gmelin). Intermediate Beach, locality 7477, U. S. Nat. Mus. 352614, ×1½. (p. 92)



MacNeil, Mertie, and Pilsbry, Fossils from Nome Beaches



MacNeil, Mertie, and Pilsbry, Fossils from Nome Beaches

SPISULA (MACTROMERIS) aff. S. POLYNYMA (Stimpson)
Plate 16, figures 1, 2

Fragments of a large *Spisula* in Nome beach collections were identified by Dall as *Spisula polynyma* Stimpson var. *alaskana* Dall, but the lunular area of the Nome specimens is not as depressed as in the Recent form. The angle formed by the dorsal margins of the Nome form is noticably greater than that of typical *S. alaskana*. This form may warrant a new subspecific name, at least, but owing to the poor preservation of the material at hand none is proposed at present.

The figured specimens are numbered U. S. Nat. Mus. 499092 and 499093. Fragments indicate that the species attains well over 100 mm. in length.

Occurrence.—Intermediate Beach, localities 5074, 7619, 14866; Second Beach, 5078, 7618.

MYA sp. indet.
Plate 16, figure 3

It is impossible to identify specifically the fragments representing this genus. Only umbonal fragments are at hand, giving no clue as to the actual shell outline. About other characters Dall stated,

> The chondrophore is more oblique than in any Recent American species and resembles that of *Mya japonica*, but the receptacle of the flatter valve is entirely different in details from that of any boreal species, all of which have been compared with it. This leads to the conclusion that it represents a distinct species, but I refrain from naming it until specimens showing the characters of the entire shell have been collected.

Figured specimen, U. S. Nat. Mus. localities 499094.

Occurrence.—Inner Submarine Beach, localities 7623, 14865; Intermediate Beach, 5074, 7477, 14866; Second Beach, 5077.

PANOMYA AMPLA Dall
Plate 16, figures 7, 10

The figured specimen, the most complete in the Nome beach collections, does not appear to differ in any significant respect from Recent specimens of this species.

Figured specimen (U. S. Nat. Mus. 324399) measures: height, 45.5 mm.; length, 71.2 mm.; convexity, 14.2 mm.

Occurrence.—Intermediate Beach, localities 4538, 5074, 14866; Second Beach, 5078, 7618.

SAXICAVA ARCTICA (Linnaeus)
Plate 15, figure 16

Typical specimens of this species occur in several of the Nome beach collections.

Figured Specimen, U. S. Nat. Mus. 499095.

Occurrence.—Inner Submarine Beach, localities 7620, 14865; Intermediate Beach, 7477, 14866; Second Beach, 3752, 5078a, 7618.

EXPLANATION OF PLATE 16

FIGS. *1, 2—Spisula* (*Mactromeris*) aff. *S. polynyma* (Stimpson). Intermediate Beach, locality 14866. ×1; *1*, exterior of a left valve, U. S. Nat. Mus. 499092; *2*, hinge of a left valve, 499093. (p. 93)

3—Mya sp. indet. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499094, ×1. (p. 93)

4–6—Pholadidea penita (Conrad). Second Beach, locality 3752; *4*, limestone boulder with borings, one individual in place, U. S. Nat. Mus. 499097, ×½; *5*, a calloused right valve, 499098, ×1; *6*, an uncalloused left valve, 499099, ×1. (p. 94)

7, 10—Panomya ampla Dall. Second Beach, locality 7618, U. S. Nat. Mus. 324399, ×1; *7*, exterior; *10*, interior. (p. 93)

8, 11, 13, 14—Diestothyris aff. *D. frontalis* (Middendorff). *8, 11*, Side and dorsal views, respectively, ×1½, Intermediate Beach, locality 14866, U. S. Nat. Mus. 499100; *13, 14*, interior of ventral and dorsal valves, respectively, of a small specimen, ×3, Inner Submarine Beach, locality 14865, U. S. Nat. Mus. 499101. (p. 94)

9, 15, 18, 19—Hemithyris psittacea alaskana Dall. Third Beach, locality 5076, ×1½; *9, 15*, interior and exterior of a dorsal valve, U. S. Nat. Mus. 499102; *18, 19*, exterior and interior of a ventral valve, 499103. (p. 94)

12—Myriozoum subgracile d'Orbigny. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499105, ×1. (p. 94)

16—Balanus rostratus alaskensis Pilsbry. Exterior, ×1, Intermediate Beach, locality 14866, U. S. Nat. Mus. 499107. (p. 94)

17—Schizmopora sp. Intermediate Beach, locality 14866, U. S. Nat. Mus. 499106, ×2. (p. 94)

SAXICAVA PHOLADIS (Linnaeus)
Plate 15, figures 11, 13

A single specimen of this species is present from the Second Beach.

Figured specimen (U. S. Nat. Mus. 499096) measures: height, 10.3 mm.; length, 21.7 mm.; convexity, 4.1 mm.

Occurrence.—Intermediate Beach, locality 5074; Second Beach, 3752.

PHOLADIDEA PENITA (Conrad)
Plate 16, figures 4–6

A limestone boulder containing 6 individuals of this species was taken from a mine dump on the Second Beach. The specimens inside are well preserved, although partially exposed borings on the side are well worn.

The width of the posterior end of the shells from Nome is like that of *P. penita*, which has not been taken living north of the Chirikoff Islands, rather than that of *P. ovoidea* (Gould), which now ranges into Bering Sea.

Figured specimens, U. S. Nat. Mus. 499097–499099. The larger of the valves figured measures: height, 19.6 mm.; length, 35.0 mm.; convexity, 10.0 mm.

Occurrence.—Second Beach, locality 3752.

BRACHIOPODA

HEMITHYRIS PSITTACEA ALASKANA Dall
Plate 16, figures 9, 15, 18, 19

Hemithyris psittacea Gmelin var. *alaskana* DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 34, pl. 5, figs. 4, 5.

Except for two incomplete valves from the Intermediate Beach at station 4538, this species is known from only the Second and Third beaches, where it is abundant.

The ventral valve figured by Dall has apparently since been broken, and the figured dorsal valve is selected as lectotype.

Lectotype (U. S. Nat. Mus. 324313) measures: length, 21.5 mm.; width, 25.0 mm., convexity, 1.5 mm. Figured specimens, 499102, 499103.

Occurrence.—Second Beach, localities 7618 (type), 5077; Third Beach, 5075, 5076; Intermediate Beach, 4538.

DIESTOTHYRIS aff. D. FRONTALIS (Middendorff)
Plate 16, figures 8, 11, 13, 14

Megasella aleutica DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 34.

This form is most similar to *D. frontalis*, but the specimens at hand are definitely narrower than the living species. Dr. G. A. Cooper, who kindly made the above identification, feels, however, that more specimens should be measured before a new name is proposed for this form.

The larger figured specimen (U. S. Nat. Mus. 499100) measures: length, 19.5 mm., width, 14.8; double convexity, 9.7 mm. The smaller figured specimen (valves separated) is numbered 499101.

Occurrence.—Inner Submarine Beach, locality 14865; Intermediate Beach, 14866; Third Beach, 5076.

BRYOZOA

MYRIOZOUM SUBGRACILE d'Orbigny
Plate 16, figure 12

Myriozoum, n. sp., DALL, *1920*, U. S. Geol. Survey Prof. Paper 125-C, p. 34.

This species, formerly reported as new, is here identified through the kindness of Dr. R. S. Bassler.

Figured specimen, U. S. Nat. Mus. 499105

Occurrence.—Intermediate Beach, localities 7477, 14866.

SCHIZMOPORA sp. indet.
Plate 16, figure 17

This specimen was identified by Dr. R. S. Bassler.

Figured specimen, U. S. Nat Mus. 499106.

Occurrence.—Intermediate Beach, locality 14866.

VERMES

SERPULA sp.
Plate 15, figure 17

Figured specimen, U. S. Nat. Mus. 499104.

Occurrence.—Intermediate Beach, locality 14866.

DESCRIPTION OF FOSSIL CIRRIPEDIA

By Henry A. Pilsbry

CIRRIPEDIA

BALANUS ROSTRATUS ALASKENSIS Pilsbry
Plate 15, figure 10; plate 16, figure 16

This is a common Recent barnacle. The

ala has been broken from the lateral plate figured.

Figured specimen (U. S. Nat. Mus. 499107) measures: height, 35.5 mm.; width, 28.2 mm.

Occurrence.—Inner Submarine Beach, locality 14865; uncertain level, 7622; Intermediate Beach, 4538, 5074, 7477, 7619, 14866; Third Beach, 5076; Second Beach, 3752, 5078a, 5078.

BALANUS CRENATUS (Bruguière)

Numerous detached wall plates agree with Recent specimens of *B. crenatus* from Bering Sea and Alaska, as figured in U. S. National Museum Bulletin 93, plate 41, figures 3, 5. This common North Atlantic species is known to occur in west American waters from Point Barrow to Santa Barbara, from low tide to about 35 fathoms.

Occurrence.—Inner Submarine Beach, locality 14865; Intermediate Beach, 14866.

VERRUCA ALASKANA Pilsbry, n. sp.
Plate 15, figures 8, 9

This is a species of the group of *V. strömia* O. F. Müller, known by two rostra, one of which is selected as type, one carina and one fixed tergum. It is believed that these plates belong to one species, though to more than one individual.

The rostrum is narrower than the carina, with a produced, somewhat curved apex. The carinal half of the external surface is flattened and strongly sculptured with ridges running to the carinal margin, which is regularly serrate; the ridges, seven in number, are closely striate transversely, with impressed lines that serrate the summits of the ridges. The rest of the plate is convex, uneven, marked with irregular growth striae, and without radial sculpture, but with two deep radial grooves at the edge towards the fixed tergum, defining ridges similar to those at the carinal edge. Inside there is a deep hollow at the apex of the plate (fig. 8). The length of this plate is 4.8 mm.

The carina has the shape of a short oval with a segment cut from one end. The surface is irregular over most of its extent, but there is a series of four radial ridges at the rostral edge and two at the other edge of the excised segment.

The fixed tergum has ridges running to the rostral edge similar to the ridges on the rostrum.

This species is apparently related to the Recent *Verruca laevigata* (Sowerby) of the west coast of South America, and the complete animal would probably resemble that species, as figured in U. S. National Museum Bulletin 93, plate 8, figure 2. It is equally or perhaps more nearly related to *Verruca strömis* of northern Europe, west to Greenland, both being species of the littoral zone. Until the movable valves are found, the exact relationship of *V. alaskana* to these living species remains somewhat uncertain, though it surely belongs to the same little group that comprises all known littoral Verrucidae, the group being otherwise from deep water.

The chief difference from *V. strömia* is in the general shape and proportions of the plates and the absence of radial sculpture on the parietes.

This Pliocene species is the first *Verruca* to be found on the American west coast north of Peru. Deep-water species not nearly related to *V. alaskana* are known from Hawaii and southern Japan.

The figured specimen, a paratype (U. S. Nat. Mus. 499109) is broken slightly along the right margin. It measures 4.8 mm. in height and 2.9 mm. in width. The holotype, the other unfigured rostrum, is 499117.

Occurrence.—Intermediate Beach, locality 14866.

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A RESTUDY OF THE FORAMINIFERAL GENERA PSEUDORBITOIDES AND VAUGHANINA

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ABSTRACT—This paper presents the results of a restudy of topotype specimens of three species, *Pseudorbitoides trechmanni* H. Douvillé (the genotype), *Pseudorbitoides israelskii* Vaughan and Cole, and *Vaughanina cubensis* D. K. Palmer. The conclusion is reached that *Pseudorbitoides* and *Vaughanina* are both valid genera but they are closely related and are placed in the subfamily Pseudorbitoidinae proposed by M. G. Rutten.

H. DOUVILLÉ (1922, p. 203; 1923, p. 369, figs. 1, 2) proposed the generic name *Pseudorbitoides* for a species of Foraminifera collected by Dr. C. T. Trechmann in the Upper Cretaceous *Barrettia* bed at Green Island, Jamaica. Doctor Trechmann sent a few topotype specimens to Vaughan, and they formed the basis of a redescription of the genus (Vaughan, 1929, pp. 168, 169, pl. 21, figs. 4–6). The same material is used in the present paper. Dorothy K. (Mrs. R. H.) Palmer (1934, pp. 240–243, pl. 12, fig. 5; pl. 13, figs. 2, 4; text figs. 2, 3) described *Vaughanina* from the Upper Cretaceous of Habana Province, Cuba, from a locality "approximately 1 kilometer west of Central San Antonio on the railroad to Central Hershey," Palmer station 1214.

Because of uncertainty regarding several features it seemed important to restudy topotype material of both genera. No additional specimens from Jamaica were available, but Mrs. Palmer sent many specimens from the type locality of *Vaughanina*, and from these 18 thin sections were made. The authors thank both Doctor Trechmann and Mrs. Palmer for their help.

Genus PSEUDORBITOIDES H. Douvillé, 1922

Genotype, *Pseudorbitoides trechmanni* H. Douvillé.

PSEUDORBITOIDES TRECHMANNI H. Douvillé
Plate 17, figures 5, 6

Pseudorbitoides trechmanni H. DOUVILLÉ, *1922*, Soc. géol. France, Comptes rendus, p. 203, fig. 1.
——H. DOUVILLÉ, *1923*, idem, Bull., sér. 4, t. 23, p. 369, figs. 1, 2.
——VAUGHAN, *1929*, Jour. Paleontology, vol. 3, p. 168, pl. 21, figs. 4–6.

It is not necessary to repeat the published descriptions of Douvillé and Vaughan, but a few supplements should be made.

The median section figured by Vaughan (1929) shows an initial spiral, but the details of the chambers composing it are not clear. The total diameter of the spiral is about 210μ; the initial chamber is about 40μ in diameter; and it is followed by about 9 chambers, which grade into the adjacent equatorial chambers. (See pl. 17, fig. 5.)

Regarding the equatorial chambers, Vaughan (1929, p. 168) said:

> Above the chambers are radiating lines, a line over or near the bounding walls of the rows and in places, at least, two lines are over the chamber cavities. The significance of these lines was not ascertained.

A restudy of the section by reflected light with a binocular microscope shows that the radiating lines represent radial plates, many of which cut across the equatorial chambers, which, however, are distinct from the center to the periphery. There are no distally developed annular walls such as are characteristic of *Vaughanina*.

M. G. Rutten (1935, pp. 543, 544) has identified specimens from south of Camajuaní, Cuba, as *Pseudorbitoides trechmanni*, and he has described their structure, which has been greatly changed by mineralization. According to Rutten's description and fig-

ures, the structure does not accord with that of *Pseudorbitoides*. Furthermore, the profiles of the vertical sections seem different from the profiles of *P. trechmanni*, which is distinctly lenticular.

W. P. Woodring has recently collected at a place 3.3 miles northwest of Plaisance, Haiti, in a *Barrettia*-bearing limestone megalospheric specimens of a species of *Pseudorbitoides* which seems to be *P. trechmanni*. A good vertical section of a specimen is 2.2 mm. in diameter and 1.0 mm. thick; ratio, diameter:thickness, 2.2. Another specimen is 1.50 mm. in diameter and 0.52 mm. thick; ratio, diameter:thickness, 2.9.

PSEUDORBITOIDES ISRAELSKII
Vaughan and Cole
Plate 17, figures 1, 2

Pseudorbitoides israelskii VAUGHAN and COLE, *1932*, Nat. Acad. Sci. Proc., vol. 18, p. 614, pl. 2, all figs.

This species will not be redescribed, but illustrations of two properly oriented sections of topotypes are given. Plate 17, figure 1, illustrates an equatorial section. There are two embryonic chambers followed by a spiral of eight periembryonic chambers. Toward the periphery there are radiating plates, but their relation to the equatorial chambers is not shown. Comment on the vertical section plate 17, figure 2, is unnecessary.

The type locality of the species is Welch well no. 1 of the Evansville Investment Co., sec. 2, T. 14 N., R. 8 E., Franklin Parish, Louisiana, depth between 4167 and 4172 feet. Upper Cretaceous.

M. G. Rutten (1935, pp. 543, 544) has identified specimens from south of Camajuaní, Cuba, as *Pseudorbitoides israelskii*, and he may be correct.

Watson H. Monroe has recently submitted to T. W. Vaughan well samples (McRae no. 1, sec. 24, T. 7 N., R. 1 W., Hinds County, Miss., depths 3909–3916, and 3916–3922 ft.) in which *Pseudorbitoides israelskii* is abundant. This species closely resembles *P. trechmanni*, but in general it seems to be more inflated and to have thicker pillars. It appears to occur at a lower horizon than *P. trechmanni*.

Genus VAUGHANINA Palmer, 1934

Genotype, *Vaughanina cubensis* Palmer.

VAUGHANINA CUBENSIS Palmer.
Plate 17, figures 3, 4; plate 18, figures 1–10

Vaughanina cubensis PALMER, *1934*, Soc. Cubana Historia Nat. Mem., vol. 8, (p. 240, pl. 12, fig. 5; pl. 13, figs. 2, 4; text figs. 2, 3).

—— VOORWIJCK, *1937*, K. Akad. Wetensch. Amsterdam Proc., vol. 40, p. 197, pl. 3, figs. 1, 2, 4, 5, 7.

Mrs. Palmer's description of the exterior is excellent, but some features need to be emphasized. The test consists of two parts, a central umbonate, lenticular part, on which are prominent papillae, and an outer thin flange, which entirely surrounds the lenticular part and which is crossed by radiating plates (pl. 17, fig. 4). The elevation that forms the lenticular part is composed of lateral chambers, which grow outward and cover the proximal edges of the flange. The flange is crossed radially by thin plates, which pass over its distal edge and produce a crenate margin. In small specimens the plates across the edge are continuous from one face to the other, but in larger specimens the plates are interrupted in the middle between the two faces. Specimens of the latter kind when sectioned vertically show two or three layers of equatorial chambers.

In equatorial sections there are outside the embryonic chambers three concentric circles of structures. The structures from the center outward are (1) the embryonic chambers, (2) periembryonic chambers, (3) several cycles of equatorial chambers, (4) annular chambers crossed by radial plates

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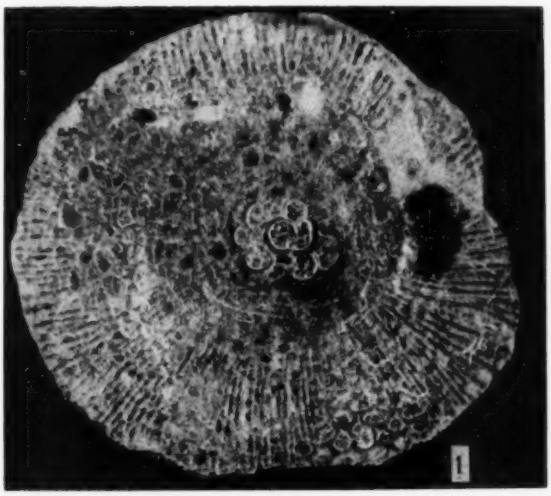
EXPLANATION OF PLATE 17

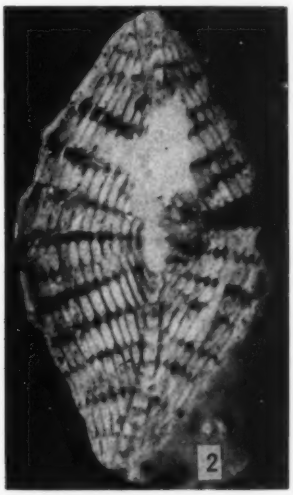
All figures taken by reflected light. All specimens are topotypes.

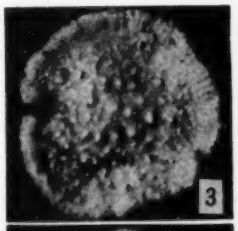
FIGS. *1–2—Pseudorbitoides israelskii* Vaughan and Cole. *1*, Equatorial, *2*, vertical section, ×37.5. (p. 98)

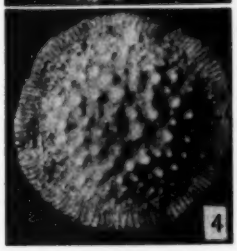
3–4—Vaughanina cubensis D. K. Palmer. Exteriors, ×20, to show ornamentation and variation in form. (p. 98)

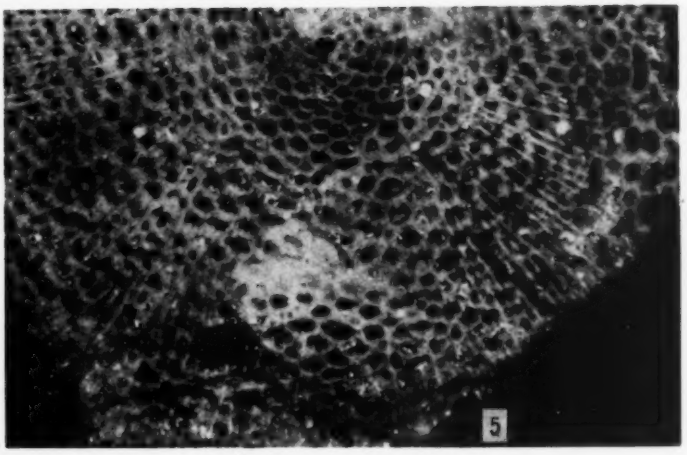
5–6—Pseudorbitoides trechmanni H. Douvillé. *5*, equatorial; *6*, vertical section, ×40. (p. 97)

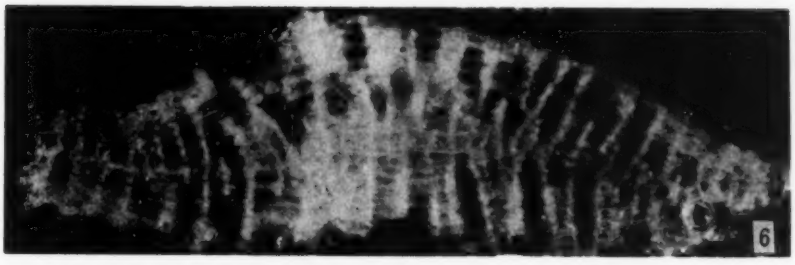




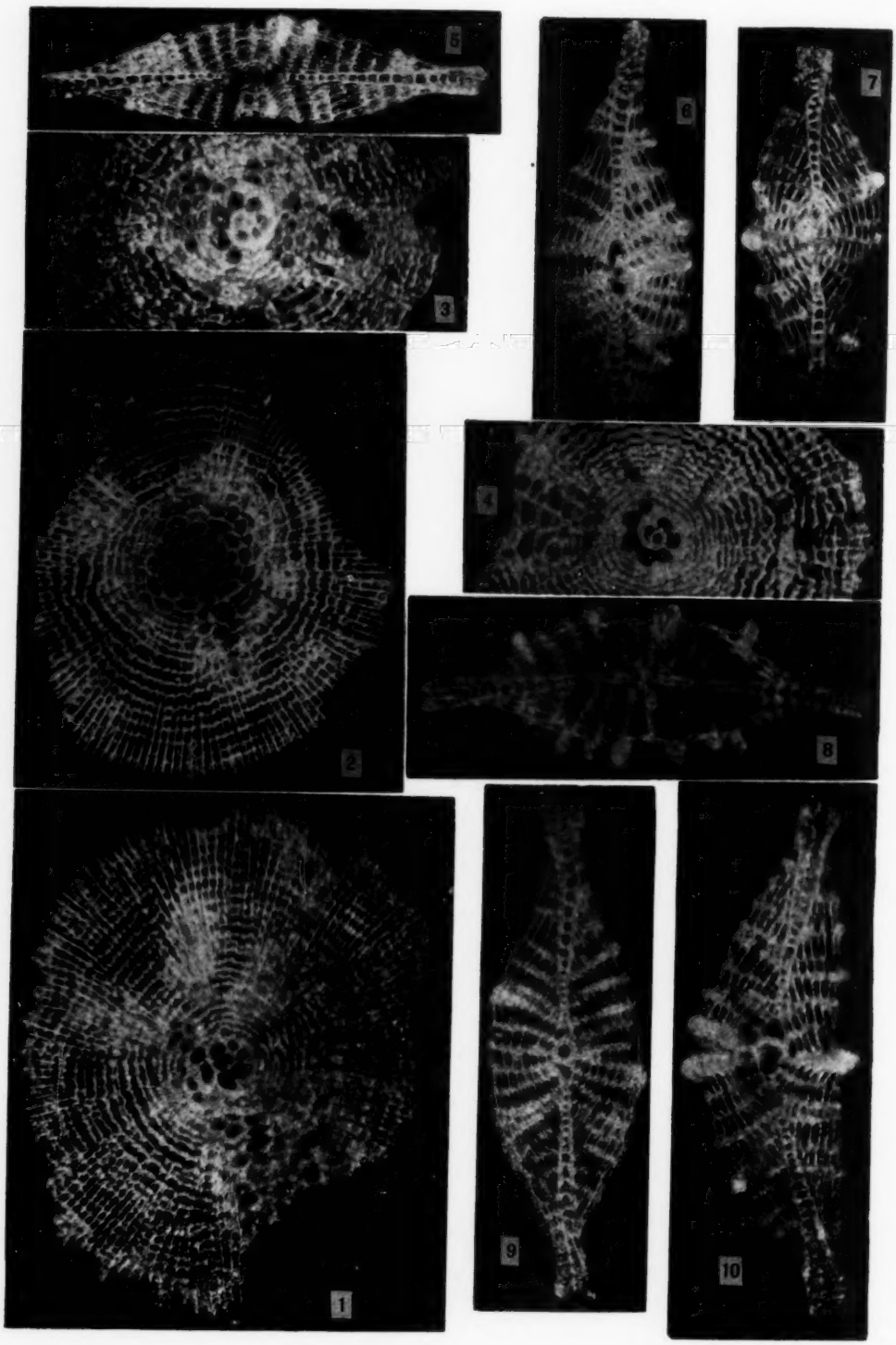








Vaughan and Cole, *Pseudorbitoides* and *Vaughanina*



Vaughan and Cole, *Vaughanina cubensis* D. K. Palmer

producing rectangular chamberlets. These different structures will be described beginning with the embryonic chambers.

There are in megalospheric specimens (pl. 18, figs. 1, 3, 4) two embryonic chambers. The initial chamber is spherical, with an internal diameter of about 30μ; the second chamber has internal diameters of 50 by 25μ. The wall between these chambers is thin, but their outer walls are thick, nearly 20μ as seen in some median sections.

There is a spiral of six to eight periembryonic chambers, which completely encircles the embryonic chambers in some specimens but only partially surrounds them in other specimens. These chambers are rudely quadrate in shape, normally increasing in size as added; the first of them has internal diameters of 40 by 40μ, the largest has internal diameters of 50 by 60μ. The total distance across the spiral is about 240μ; its thickness is about 60μ. Foramina occur on the proximal sides of the walls between the chambers in the spiral.

Outside the periembryonic spiral usually a variable number of normal equatorial chambers can be recognized (pl. 18, figs. 1–3). These chambers, although variable in shape, in general have curved outer walls and more or less truncate inner ends. The radial diameter of an average chamber is about 40μ; the tangential diameter, about 70μ. It appears that there are passages for stolons at the inner ends of the curved outer walls.

On the periphery of the equatorial chambers described above a change begins. Radial plates appear, and they cut entirely across the equatorial layer as was noted in describing the exterior of specimens. The outer walls of the normal equatorial chambers fuse and form annular wells producing annular chambers, which are crossed by the radial plates just mentioned, resulting in the formation of successive circles of rectangular chamberlets. These chamberlets replace the initial equatorial chambers. The distance between the radial plates at the periphery is about 20$\mu \pm$; that between the annular walls ranges from 20 to 40μ.

In vertical section the equatorial layer is distinct, gradually increasing in height toward the periphery of the test. At the center of the test the height of the layer is approximately 30μ and at the periphery about 100μ. These measurements include the roofs and floors. Near the periphery of the test the layer appears to have three divisions.

The lateral chambers are open, distinct, with relatively thin floors and roofs. They are normally arranged in regular tiers with six to eight chambers to a tier on each side of the equatorial layer at the center of the test, and they decrease regularly in number as the periphery of the test is approached. The flange is not covered by lateral chambers. The length of the lateral chambers over the center of the test and near the periphery ranges from 60 to 100μ, and the height ranges from 15 to 20μ. Pillars are irregularly present. Some specimens have more pillars than others. A common surface diameter of a pillar is about 60μ, although the range is from 40 to 80μ. Many of the pillars do not extend to the equatorial layer.

Vaughanina has many features in common with *Pseudorbitoides*, but there are noteworthy differences. *Pseudorbitoides trechmanni* has radial plates similar to those of *Vaughanina*, but the normal equatorial chambers are developed entirely to the periphery of the test, and there are no annular walls. *Pseudorbitoides israelskii* possesses radial plates but lacks annular walls. Apparently the normal equatorial chambers extend to the periphery of the test.

The diagnostic difference between *Vaughanina* and *Pseudorbitoides* consists in the development of annular walls in *Vaughanina* and the peripheral replacement of normal equatorial chambers by rectangular chamberlets. The two genera seem to belong in the Orbitoididae, but the possession of a pronounced initial spiral in the megalospheric generation and the presence of the

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EXPLANATION OF PLATE 18

All figures ×37.5, taken by reflected light. All specimens are topotypes.

FIGS. *1–10*—*Vaughanina cubensis* D. K. Palmer. *1–4*, Horizontal sections; *5–10*, vertical sections.

(p. 98)

radial plates suggest that they should be placed in a separate subfamily, the Pseudorbitoidinae of M. G. Rutten (1941, p. 38). Although Rutten proposed this subfamily for the genus *Pseudorbitoides* and recognized that there was a general similarity of structure between *Pseudorbitoides* and *Vaughanina* (1941, p. 37), he did not have preparations to study the equatorial layer. As Mrs. Palmer had described the equatorial layer as an undivided spiral tube, Rutten considered that *Vaughanina* belonged to the Planorbulinidae, following the original suggestion of Mrs. Palmer.

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NEW LOWER ORDOVICIAN TRILOBITES FROM LEVIS, QUEBEC

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ABSTRACT—A lower Ordovician boulder in the Levis formation yielded trilobites representing species of *Kainella*, *Diplapatokephalus*, *Onchonotus*, and two new genera, *Levisaspis* and *Loganopeltis*. Five new species are described, and *Concephalites zenkeri* Billings is transferred to *Loganopeltis*.

INTRODUCTION

FOR ALMOST a century, the rocks of Levis have been the object of study by leading geologists and paleontologists. Nevertheless, the knowledge of their faunas is still far from complete. The author, focusing his attention on the limestone conglomerates containing pebbles of Lower Cambrian, Upper Cambrian and Lower Ordovician age (Clark 1924) has brought to light a number of still undescribed forms, and many more will certainly be revealed by further search. The author is at present unable to give a complete description of these new forms, most of which are Upper Cambrian. However, he believes that it may be worth while to describe a small group of new trilobites found in Lower Ordovician rocks, for the following two reasons. First, among these trilobites there occur two new genera, which are represented by more complete specimens than it is usually the case for trilobites of this age and locality. Secondly, all the forms to be described were found to occur together, associated with well-known Lower Ordovician species, so that their description may contribute to increase our knowledge of a well-defined faunal assemblage.

LOCALITY AND AGE OF THE FOSSILS

All of the species to be described were found at Levis in a Lower Ordovician limestone boulder from the conglomerate band designated by Logan (Logan, 1863; Clark, 1924) as band 4. The outcrop is on the summit of the hill known in the geologic literature as North Ridge. Besides the species here described, the boulder contained: *Leiostegium* (3 species), *Symphysurina* sp., *Pilekia eryx* (Billings), *Pilekia apollo* (Billings).

The two latter species are known to occur in the Highgate and Grandge formations of northwestern Vermont, which Raymond (1924, 1937) considers to be at the base of the Ordovician. Ulrich (Ulrich and Cooper, 1938) designates formations of this age as "Upper Ozarkian." The presence of *Kainella* suggests correlation with the Mons formation of Alberta, which Ulrich also designates as Upper Ozarkian.

SYSTEMATIC DESCRIPTIONS

Genus LEVISASPIS RASETTI, n. gen.

Small proparian trilobites shortly oval in shape. Cephalon rather strongly convex, with a concave brim all around and no rim. Glabella narrow, cylindrical, convex in the transverse direction, and flat longitudinally; occupying somewhat more than half the length of the cranidium, unfurrowed except for the occipital furrow. Eyes small, close to the anterior end of the glabella. The ocular ridges have a horizontal direction. Posterolateral limbs extended into short genal spines. Free cheeks small, anterior in position, subtriangular. Anterior branch of the facial suture directed almost straight forward from the eye, then curving inward, becoming intramarginal for a short distance.

Thorax of five segments. Axis narrow, prominent. Pleura flat, furrowed, pointed at the ends but not extending into spines.

Pygidium wide and short. Axis prominent, conical, with a few segments. Pleural lobes flat, well fused, with a concave brim.

Genotype, *L. typicalis* Rasetti, n. sp.

Remarks.—This trilobite does not appear to present close affinity with any described genus. The form of the cephalon suggests some resemblance to *Hardyoides* Kobayashi, from which it is readily distinguished by the absence of a rim.

LEVISASPIS TYPICALIS Rasetti, n. sp.
Plate 19, figures 13–15

The generic description combined with the illustrations shows most of the characteristics of this species.

Glabella twice as long as wide, slightly expanding in front; anterior outline somewhat pointed. Occipital furrow well marked all across the cephalon. Thoracic axis occupying slightly more than one-fourth of the width of the thorax. Pygidium three times as wide as long. Axis almost reaching the posterior border. Two shallow pleural furrows visible; pleural grooves obsolete. Width of whole trilobite about three-quarters of length. Length of largest specimen about 5 mm.

A couple of square inches of the surface of the rock are covered with the shields of this species. Some specimens retain the cephalon and thorax, others the thorax and pygidium, and there is a somewhat imperfect complete specimen.

Syntypes, Laval Univ. no. 1296.

Genus KAINELLA Walcott, 1925
KAINELLA ORIENTALIS Rasetti, n. sp.
Plate 19, figures 11, 12

Known from one cranidium and one pygidium. Glabella quadrate, with a shallow, oblique posterior pair of furrows and only a trace of another pair. Width of brim less than one-fifth the length of the glabella; brim crossed by irregular obscure ridges. Rim almost as wide in the middle as the preglabellar area. There is the usual row of puncta just inside the rim. Sutures as in genotype.

Pygidium width one and one-half times its length (excluding the spines). Axis with five rings besides the terminal segment, which extends into a postaxial ridge as usual with the genus. Two ribs on each pleural lobe, strongly curved inward, extending beyond the border into spines.

Length of cranidium, 24 mm., width measured between the extremities of the anterior lobes, 34 mm. Length of pygidium, 27 mm., width 40 mm.

This species appears to be readily distinguished from the genotype, *K. billingsi* Walcott, and from other described species, by the width of the pygidium and the strong curvature of the spines.

The occurrence of *Kainella* in the Levis conglomerates has been known for a long time, as it is referred to by Walcott in describing the genus. However, as far as I know, no species has ever been described from this or any other eastern locality.

Holotype (pygidium), Laval Univ., no. 1277; paratype (cranidium), no. 1271.

Genus DIPLAPATOKEPHALUS
Raymond, 1937
DIPLAPATOKEPHALUS LEVISENSIS
RASETTI, n. sp.
Plate 19, figures 7–10

Cranidium of the usual general shape found in *Apatokephalus* and allied genera. Glabella slightly longer than its maximum width, expanding between the eye-lobes, so that there is no fixed cheek. Glabella almost flat in the posterior half, while the anterior part curves down, meeting the brim at a high angle. Occipital segment wide, separated by a narrow furrow. Three pairs of glabellar furrows. The first two pairs are shallow and extend in a transverse direction from the dorsal furrow across one-third the width of the glabella. The third pair unite across the glabella, forming the shape of a double S. Palpebral lobes large, extending from the occipital furrow to about three-quarters of the length of the glabella. From the anterior end of the palpebral lobe, the suture is in contact with the glabella and is directed downward, as the brim is at a much lower level than the palpebral lobes, and then straight outward. Brim narrow, limited by a thick, convex, striated rim. Just inside the rim there is a row of punctae. Surface of glabella and brim pustulose. Posterolateral limbs not preserved.

Free cheeks wide, with a striated rim which extends into long, curved genal spines. The margin of the cheek back of the genal spine forms an angle of about 30° with the axis of the body for some distance, then turns sharply inward. There is thus formed an obtuse intergenal spine. Surface of free cheek with irregular, anastomosing transverse ridges.

Hypostoma and thorax unknown.

Pygidium twice as wide as long, fan-shaped. Axis prominent, conical, with three rings besides the terminal segment, which extends into a postaxial ridge almost reach-

ing the border. Five pairs of flat furrowed pleura; pleural grooves almost obsolete. Each pleuron extends into a flat spine; first four spines slightly decreasing in length, the innermost pair much smaller than the others. Upper surface pustulose; impression of doublure with transverse, irregular striae.

Length of largest cranidium, 14 mm.; width at palpebral lobes, 12 mm. Length of large pygidium, 10 mm.; width 20 mm.

Many fragments belonging to this species occurred closely associated together in a portion of the boulder.

Raymond erected the genus *Diplapatokephalus* for forms with furrowed pygidial pleura. From the genotype, *D. finalis* (Walcott), the present species differs by the pustulose surface, the wider glabella and other details.

Syntypes, Laval Univ., nos. 1262, 1266, 1276, 1282, 1283.

Genus ONCHONOTUS Raymond, 1924

ONCHONOTUS FOVEOLATUS Rasetti, n. sp.
Plate 19, figures 4–6

Cephalon highly convex in both directions. Glabella ovate, convex, with a deep occipital furrow separating a rather wide, prominent occipital segment. One pair of glabellar furrows, shallow, obliquely directed. Eyes relatively large for the genus, prominent. Free cheeks with short genal spines. There is a narrow convex rim all around the cephalon. Posterior branch of facial suture separating rather wide triangular posterolateral limbs. Anterior suture directed almost straight forward from the eye and then curving inward, remaining slightly intramarginal to the center.

Length of cephalon, 3 mm.; width, 4.5 mm. Thorax and pygidium unknown.

Several excellently preserved cephala and cranidia were found closely associated with *Pilekia eryx* and *Loganopeltis*. This form is readily distinguished from the Upper Cambrian species, which are the most common fossils in the Levis conglomerates, by the smaller size, the more markedly impressed posterior glabellar furrows and the relatively larger eyes.

Holotype, Laval Univ., no. 1249.

Genus LOGANOPELTIS Rasetti, n. gen.

Multisegmented trilobites with a large semicircular cephalon and a small pygidium. Cranidium without dorsal sutures. Glabella conical, with three pairs of furrows. Circumglabellar area convex, radially striated, surrounded by a concave upturned brim. Eyes conical, close to the anterior end of the glabella; eye ridges strong. The free cheeks probably consisted of a single ventral plate.

Thorax with about 20 segments and a narrow axis. Pleura grooved, curving backward at the ends, especially the posterior ones.

Pygidium small, longer than wide. Axis short, conical. Pleura curving backward, terminating into a pair of flat spines. The pygidium somewhat resembles a small pygidium of *Hungaia*.

Genotype, *L. depressa* Rasetti, n. sp.

Remarks.—This genus does not seem to be closely allied to any described. It bears some resemblance to *Harpes* and *Entomaspis;* however, the differences from both are conspicuous. *Harpes* has long genal spines, which are lacking in the present genus; *Entomaspis* has a rim around the cranidium. Moreover, Ulrich (1930) states that *Entomaspis* probably has few thoracic segments. Finally, the structure of the pygidium is altogether different from that found in *Harpes*, *Entomaspis*, and most hypoparian trilobites.

LOGANOPELTIS DEPRESSA Rasetti, n. sp.
Plate 19, figures 1–3

Cranidium semicircular, depressed. Glabella occupying half the length of the cranidium, with three pairs of furrows. First and second pair short and shallow, having a transverse course. Third pair longer, oblique, and more deeply impressed. Occipital furrow well impressed all across the cranidium. Neck segment widest at the middle of the glabella, where it is provided with a low tubercle. Convex area of the cheeks with irregular radially arranged striae, which give place to large rounded tubercles in the concave brim. Border of the brim upturned but low. Eyes conical, prominent. Cranidium without genal spines. No genal spines seem to have been present on the ventral plate either, but the evidence on this point is not certain.

Thorax with probably about 20 segments (16 segments visible in the incomplete thorax of holotype). Axis narrow. Pleura

with a furrow that divides them into a narrower anterior and a wider posterior part. The first pleura are bent backward only toward the end, but the last ones are turned backward for about half of their length. The last pleura probably enveloped the pygidium.

Pygidium with axis occupying about half the length, conical, with three segments besides the terminal section, which extends into a ridge. Pleural lobes flat, with four pairs of ribs, which turn backward and somewhat inward, terminating into a pair of flat spines. Thus the posterior border of the pygidium is notched in the form of an inverted V. Thorax and pygidium smooth.

An almost complete specimen, a large number of cranidia and several pygidia occurred in a portion of the boulder, closely associated with *Pilekia eryx*.

Holotype, Laval Univ., no. 1265.

LOGANOPELTIS ZENKERI (Billings)

Conocephalites zenkeri BILLINGS, *1863*, Paleozoic fossils of Canada, vol. 1, p. 398, fig. 375.
Ptychoparia zenkeri, MILLER, *1889*, North American Geology and Paleontology, p. 565.

The assignment of this species among the Opisthoparia is probably due to the fact that the ridges represented in Billings' illustration of the cranidium were taken for sutures. Actually, there are no dorsal sutures, and the ridges in question are often indistinct, as stated by Billings himself.

Conocephalites zenkeri is obviously closely allied to *Loganopeltis depressa* and may be placed in the same genus, especially since the author found, associated with the cranidia, pygidia which show the same structure as those of *L. depressa*. The cranidium of *L. zenkeri* differs by the larger and much more convex glabella, the higher upturned brim, and the ornamentation of the brim, which consists only of radiating striae. There are also two flat tubercles near the base of the glabella, which are indistinct in *L. depressa*.

The pygidium associated with *L. zenkeri* differs from that of *L. depressa* by the pleura being more sharply turned backward and by the presence of one more pair of pleural ribs. The surface is minutely pustulose.

This species occurs rather uncommonly in the Upper Cambrian boulders at Levis, associated with *Hungaia magnifica* (Billings).

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EXPLANATION OF PLATE 19

All the species illustrated are from a Lower Ordovician boulder in the Levis formation at Levis, Quebec.

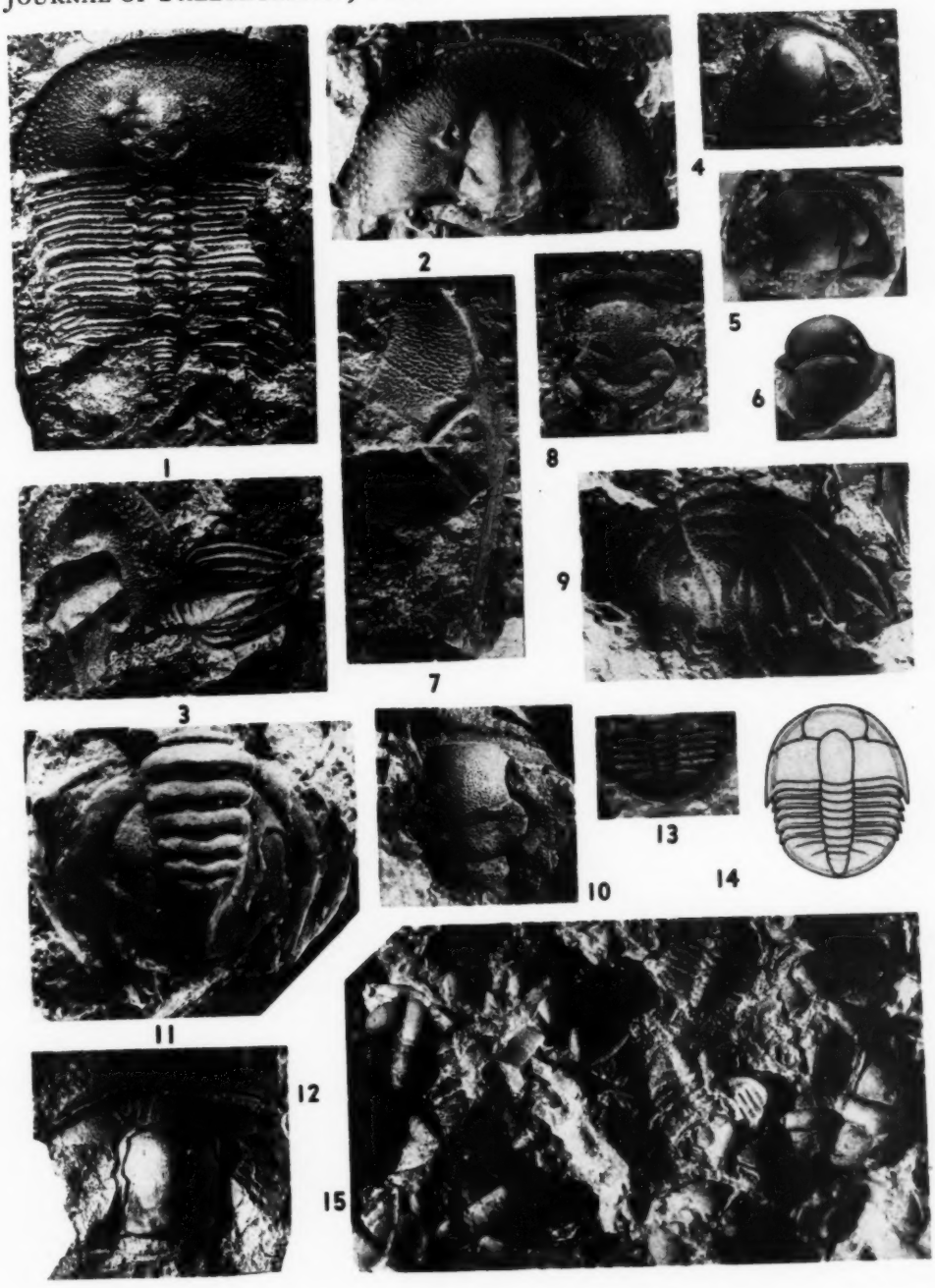
FIGS. *1–3—Loganopeltis depressa* Rasetti, n. sp. *1*, Holotype, ×2.5; *2*, cranidium, ×2.5; *3*, small cranidium and pygidium, ×4. (p. 103)

4–6—Onchonotus foveolatus Rasetti, n. sp. *4*, Cephalon (paratype), ×5; *5*, *6*, top and side view of cephalon (holotype), ×5. (p. 103)

7–10—Diplapatokephalus levisensis Rasetti, n. sp. *7*, Free cheeks, ×2; *8*, small cranidium, ×3.5; *9*, pygidium, ×2; *10*, cranidium, ×2. All syntypes. (p. 102)

11, *12—Kainella orientalis* Rasetti, n. sp. *11*, Pygidium (holotype), ×1; *12*, cranidium, ×1. (p. 102)

13–15—Levisaspis typicalis Rasetti, n. sp. *13*, Four thoracic segments and pygidium, ×5; *14*, restored outline of entire shield, ×5; *15*, surface of limestone covered with shields of this species, ×5. Syntypes. (p. 102)



Rasetti, Lower Ordovician Trilobites

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JOURNAL OF PALEONTOLOGY, VOL. 17, NO. 1, PP. 105–109, PL. 20, 1 TEXT FIG., JANUARY 1943

SOME UNUSUAL CYSTOIDS AND CRINOIDS FROM THE NIAGARAN (SILURIAN) OF WEST-CENTRAL OHIO

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ABSTRACT—A revised column of the Niagaran sequence of west-central Ohio is presented. The three uppermost formations, the Cedarville, Huntington (restricted), and New Corydon are briefly described. Well-preserved internal molds of the cystoid *Holocystites greenvillensis* Foerste, from the Huntington (restricted), and the crinoid *Callicrinus primibrachialis*, n. sp., from the Cedarville, are described.

DURING the course of a detailed stratigraphic and faunistic study of the Niagaran formations of west-central Ohio and adjacent northern Indiana 278 species of fossils were collected and identified. Nine of these species are cystoids and 24 are crinoids. This is a considerable expansion of the known forms of echinoderms from the Niagaran dolomites of this area. With the exception of two species, all of these echinoderms were collected from the Cedarville and Huntington (restricted) dolomites. One of the cystoids, previously described by A. F. Foerste, and one of the crinoids are of particular interest and are the main subject of this report.

The Niagaran sequence of west-central Ohio has been somewhat modified as a result of the stratigraphic studies. It is as follows:

Niagara group.
- New Corydon limestone
- Huntington (restricted) dolomite
- Cedarville dolomite
- Springfield dolomite
- Euphemia dolomite
- Massie shale
- Laurel limestone
- Osgood shale
- Dayton limestone

The three uppermost formations are the modified portion of the previously accepted Niagaran sequence in west-central Ohio. Any consideration of the subjacent formations will be omitted, inasmuch as adequate descriptions of them may be found in the literature.

CEDARVILLE FORMATION

The Cedarville is a white to blue-gray, holocrystalline, porous dolomite with small, irregularly outlined pockets or open spaces. These open spaces are, in many instances, due to weathering out of the cups of cystoids and crinoids. In other cases cavities are the result of solution of stromatoporoids. In west-central Ohio only the lowermost portion of this formation is exposed, and a complete section of the entire formation is not exposed at any single locality. The base of the 43-foot section of the Cedarville quarry (the type locality) in Greene County, is now known, on the basis of faunal horizons, to be 22 feet above the base of the formation as exposed in the Jenkins and Moore quarries, one mile southwest of Springfield in Clarke County, Ohio. Thus, the top of the Cedarville quarry exposure is 65 feet above the base of the formation. The Ridgeville and Fairview quarries, Randolph County, Indiana, are the only two exposures in which the upper portion of the Cedarville formation is exposed. The lower 53 feet of the 70-foot section are upper Cedarville and, on the basis of faunal zones, the lower 23 feet of this quarry are the same as the topmost 23 feet of the type section at Cedarville, Ohio. Thus, the total thickness of this formation is approximately 95 feet.

HUNTINGTON (RESTRICTED) FORMATION

The term "Huntington (restricted)" is here proposed for the strata above the Cedarville dolomite and below the New Corydon limestone. This revision is made necessary by the fact that the basal portion of the Huntington formation of Cumings and Shrock, as exposed solely in the Ridgeville and Fairview quarries, Randolph County, Indiana, is equivalent to the upper

Cedarville dolomite of west-central Ohio. Only the topmost part (17 feet) of the Ridgeville quarry exposure contains a Guelph fauna and is therefore retained as the basal Huntington (restricted). Its principal area of outcrop is in Mercer and Darke counties, Ohio, and in Randolph, Jay, Wells, and Huntington counties, Indiana.

The Huntington (restricted) is a light gray to drab, holocrystalline, porous, cavernous dolomite. The exact thickness is unknown, since a complete section is not exposed in any one locality. It is the writer's belief, however, that the thickness does not exceed 125 feet. That the Huntington (restricted) is older than the true Guelph of northern Ohio, Ontario, and New York is indicated by the presence of many species common in the underlying Cedarville formation and a similar number of different species abundant in the overlying typical Guelph. The Huntington (restricted) is correlated with the Port Byron of northeastern Illinois, the Louisville of Kentucky, and the Brownsport of Tennessee.

NEW CORYDON FORMATION

The New Corydon limestone has its typical development in northern Indiana and is here recognized for the first time in the upper portion of the Karsh Stone Co. quarry, four miles west-southwest of Celina, Mercer County, Ohio. It consists of brown cherty layers of irregularly bedded limestone. This formation ranges up to 40 feet in thickness in northern Indiana. In the Karsh quarry the basal 8½ feet of this formation rest on the Huntington (restricted) formation. Faunistically the New Corydon contains an impoverished Huntington (restricted) fauna, rather than a recurrent Lockport fauna, as was suggested earlier by Cumings and Shrock.

Grateful acknowledgement is made to Dr. J. Ernest Carman and Dr. Grace A. Stewart, both of the Department of Geology, The Ohio State University, for their valuable criticisms in the preparation of this paper.

SYSTEMATIC DESCRIPTIONS

Class CYSTOIDEA von Buch
Family SPHAERODONTIDAE Neumayr
Genus HOLOCYSTITES Hall, 1864
HOLOCYSTITES GREENVILLENSIS Foerste
Plate 20, figures 1–5

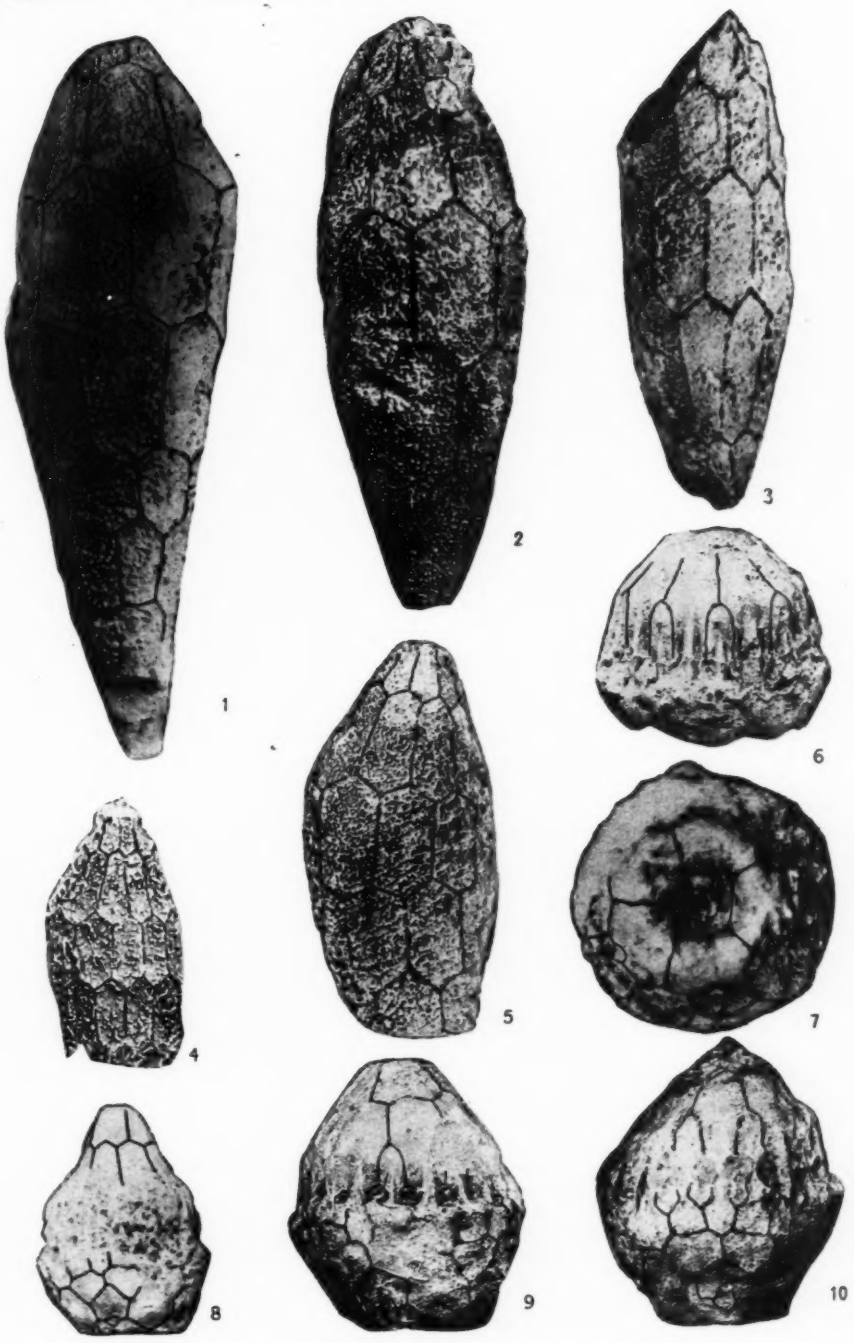
Holocystites greenvillensis FOERSTE, *1917*, Ohio Jour. Sci., vol. 17, no. 6, pp. 203–204; 233–235, pl. 9, figs. 3A–C; pl. 10, fig. 8.

Theca slightly curved, fusiform, more attenuated at the aboral end, composed of eight or nine horizontal rows of punctate plates, each row consisting of eight plates. The granulose surfaces, as shown on plate 20, figures 1–5, are the result of filling of the holes of the punctate plates, all the specimens studied being molds of the interior. In addition, some of the surfaces show fillings of cracks which represent breaks in the plates (pl. 20, fig. 5). The plates of the third row below the oral end are the largest, occupying the position of greatest diameter of the theca (pl. 20, fig. 1). All of the plates are hexagonal in outline, with the possible exception of the uppermost and lowermost series. The thickness of the plates is approximately 0.5 mm.

A circular anal opening is located near the top between the two uppermost rows of plates, as shown on plate 20, figure 2. Foerste (1920) observed that when specimens are oriented with the anal opening at the rear "the plates along the middle of the right side of the theca are narrower, while those on the left side are wider than the remainder." For the specimens under consideration all the wider and longer plates are on the convex side of the theca, which may, however, be on either the right or left side of the properly oriented theca instead of always being on the left side as suggested by Foerste. A specimen with a convex curvature on the right side of the theca is shown on plate 20, figure 1, and two specimens with a marked convex curvature on the left side of the theca are shown on plate 20, figures 4 and 5. The nature of several of the plates around the anal aperture is shown on plate 20, figure 2.

EXPLANATION OF PLATE 20

FIGS. *1–5—Holocystites greenvillensis* Foerste. (p. 106)
6–10—Callicrinus primibrachialis Busch, n. sp. (p. 107)



Busch, Silurian Echinoderms

UNIV. OF MICH.

Foerste's types consisted of only 3 incomplete, immature specimens, whereas the writer's collection contains 13 immature and 7 adult specimens. The immature specimens have an average maximum diameter of 20 mm. as compared to 28 mm. for the mature forms. Accurate comparisons of lengths cannot be made because the ends of all are broken.

Estimates of the average original lengths are 76 mm. for immature forms and 108 mm. for mature individuals.

Remarks.—In comparing this species with *Holocystites abnormis* Hall, Foerste (1920) points out that

> the plates of the upper two rows are very much narrower, especially on the right side of the theca. Moreover, the general outline is fusiform, and the outline near the anal protuberance tends to be more or less distinctively concave. In addition the size is much smaller.

All but the last of these points holds true for my specimens. The immature specimens are comparable in size to Foerste's specimens, but the mature individuals are much larger, even a little larger than *H. abnormis* Hall.

Occurrence.—Dolomite strata of Huntington (restricted) age; Rockford Stone Co. quarry, two miles northwest of Rockford, Ohio. The three specimens figured by Foerste came from dolomitic strata of the same age, exposed along Greenville Creek, four miles east of Greenville, Ohio.

Types.—Hypotypes, nos. 19251–19255, Geological Museum, The Ohio State University.

Class CRINOIDEA Miller
Order CAMERATA Wachsmuth and Springer
Genus CALLICRINUS d'Orbigny, 1849

CALLICRINUS PRIMIBRACHIALIS Busch, n. sp.
Plate 20, figures 6–10; text figure 1

Dorsal cup, as shown by internal molds, twice as wide as high, sides expanding upwards at an angle of approximately 60°, broadly truncated and deeply excavated at the base. Because of the deep excavation in the base, the lowest part of the dorsal cup is at the median portion of the large *R* (radial) circlet. *BB* (basals) and the lower part of the *RR* (radials) form the walls of the deep pentagonal excavation, which varies in depth from one-third to one-half the height of the dorsal cup; angles of the pentagonal excavation are directed toward the centers of the *RR*.

Cup above the *RR* includes two *PBrBr* (primibrachials) and two *SBrBr* (secundibrachials), as shown in text figure 1. $PBrBr_1$ (first primibrachials) very small, oval to lens-shaped, partially overlapped above by the $PBrBr_2$ (second primibrachials) which extend laterally beyond the $PBrBr_1$, and rest on the *RR*. The upper edges of the *RR* also partially overlap the lower halves of the $PBrBr_1$ which suggests that the $PBrBr_1$ were probably spiny plates inserted in the notched contiguous edges of the *RR* and $PBrBr_2$ (pl. 20, figs. 8–10). The extremely small size and peculiar shape of the $PBrBr_1$ are the most outstanding characteristics of the species, and it is for these features that the species is named.

The $PBrBr_2$, which are the $PBrBr_2Ax$ (axillary second primibrachials), are of normal size, pentagonal in outline with the aforementioned notch in the lower edge, wider than long, lateral edges vertical, and with two sloping upper edges meeting at an angle slightly over 90°.

The $SBrBr_1$ (first secundibrachials) are in contact laterally, three-fourths as large as the $PBrBr_2Ax$, wider than long and with six unequal edges. $SBrBr_2$ (second secundibrachials), which are $SBrBr_2Ax$ (axillary second secundibrachials), are much smaller and six-sided. Base nearly horizontal (fig. 1A), lateral edges nearly parallel and vertical, two upper edges sloping, and a short, horizontal edge at the top.

The $TBrBr_1$ (first tertibrachials) rest on the two sloping upper edges of the respective $SBrBr_2Ax$ (axillary second secundibrachials) and are separated by a single *ITBr* (intertertibrachial) plate; they are less than half the size of the $SBrBr_2Ax$ and have four unequal edges, the outer one of which is longest and convex outward, and the top nearly horizontal.

$IBrBr_1$ (first interbrachials) almost two-thirds as large as the *RR*, a little longer than wide, octagonal with sides of unequal length (fig. 1). $IBrBr_2$ (second interbrachials) two in number for each ray and much longer than wide. Combined areas of $IBrBr_2$ of one ray slightly more than half that of the IBr_1 (first interbrachial), in

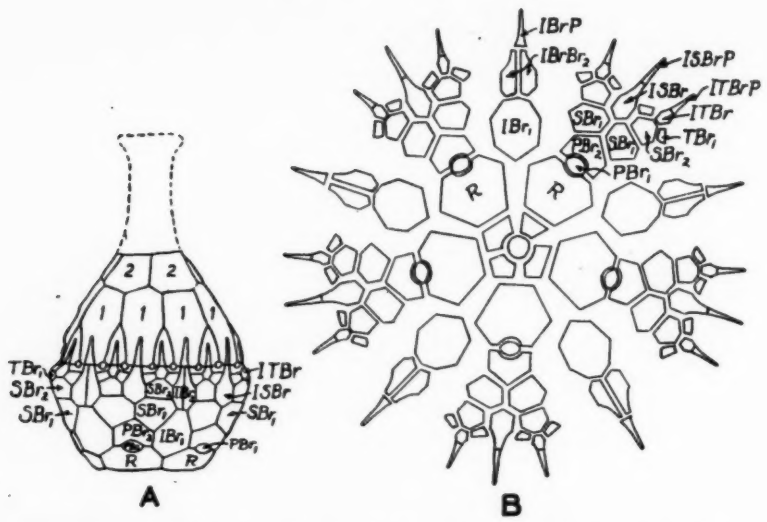


FIG. *1*—*Callicrinus primibrachialis* Busch, n. sp. *A*, Sketch showing side view of calyx, plate arrangement, and rudimentary partitions; *R*, radial; PBr_1, first primibrachial; PBr_2, second primibrachial; SBr_1, first secundibrachial; SBr_2, second secundibrachial; TBr_1, first tertibrachial; IBr_1, first interbrachial; $IBrBr_2$, second interbrachials; *ISBr*, intersecundibrachial; *ITBr*, intertertibrachial; *IBrP*, interbrachial process; *ISBrP*, intersecundibrachial process; *ITBrP*, intertertibrachial process; *1*, first or lowest circlet of plates in the tegmen (this circlet consists of 10 large and 10 small plates); *2*, second circlet of plates (upper edges broken); 3rd and 4th circlets are broken off. *B*, plan view of a dorsal cup.

contact laterally and resting on the two upper edges of the IBr_1. The *ISBrBr* (intersecundibrachials) small, elongate, unequally seven-sided and resting on the adjoining edges of the $SBrBr_1$.

This species is characterized by having a rigid tegmen composed of four circlets of plates, the total height of which is twice the depth of the dorsal cup. In my collection the tegmen is partially preserved in 8 of the 17 specimens. The first circlet and the lower halves of the second circlet of plates are all that are usually preserved. The anal tube, which comprises the fourth circlet of plates, is almost always broken because of its constricted character. The lowest circlet of plates is composed of 10 (fig. 1A) large and 10 small plates in alternating positions. The 10 large plates are elongate radially and broader distally. Five of these rest above the projecting upper edges of the paired $IBrBr_2$ and five alternate ones rest above the *ISBrBr*. The upper halves of the 10 large plates are in contact laterally, but the lower halves of the adjoining side edges diverge, leaving 10 small, triangular areas, each one of which is occupied by a small, triangular plate. At each pair of adjoining lower lateral corners of a large plate and a small plate of the first circlet there is an ambulacral or arm opening for a food groove, which passes beneath the tegmen to the protected mouth (fig. 1A). There are 20 of these ambulacral openings, which are separated by 20 partition ridges, which Angelin (Bather, 1900) refers to as processes (fig. 1A). These processes are confined to the lower half of the lowest circlet of tegmen plates. Five ridgelike partitions, the *IBrPP* (interbrachial processes), rest on the $IBrBr_2$; 5, the *ISBrPP* (intersecundibrachial processes), on the *ISBrBr;* and the 10 remaining, the *ITBrPP* (intertertibrachial processes), on the *ITBrBr*.

Only the lowest circlet of plates can be described from our specimens. Wachsmuth and Springer (1897) describe the plates of the second, third, and fourth circlets of this genus as follows:

> The plates of the second and third rings either are flat, the general curvature excepted, or they show some inclination to forming faces of attach-

ment for partition walls. The four plates of the upper ring constitute the upper end of the anal tube, which generally has a quadrangular opening.

Arms 20, situated in grooves and separated by processes on side of tegmen. Wachsmuth and Springer (1897) describe the arms of this genus further by saying:

> Arms robust throughout, closely folded and composed, from the second and third plate up, of two rows of transverse pieces. The partitions by which they are separated rarely extend up higher than to one-third the length of the arms.

C. primibrachialis is most closely related to *C. cornutus*, from which it differs principally in possessing an overspecialized PBr_1 plate, which in life was probably extended into a spine. Thus, it appears that *C. cornutus* represents an antecedent condition of *C. primibrachialis*. In all illustrated specimens of *C. cornutus* the $PBrBr_1$ are perfectly developed and clearly separate the *RR* and $PBrBr_2$. Hall (1867), in his description of *C. cornutus* (*Eucalyptocrinus cornutus* var. *excavatus*), refers to some specimens in which

> the second radial plates $(PBrBr_1)$[1] are imperfectly developed, being reduced to a mere flattened node which is entirely surrounded by the first (*RR*) and third radial plates $(PBrBr_2)$.

The illustrations accompanying his description are undoubtedly *C. cornutus*, but the specialized forms mentioned in the above quotation are not illustrated and very likely belong to *C. primibrachialis*.

[1] Author's notes in parentheses.

C. costatus differs from *C. primibrachialis* in the same respects as *C. cornutus* and in the writer's opinion is conspecific with *C. cornutus*.

Occurrence.—All specimens now known are from the Cedarville dolomite. This form has been found in the lower 60 feet of the Cedarville at the Moore Lime Co. quarry and the Jenkins quarry, both one mile southwest of Springfield, Ohio; and in the Cedarville quarry at Cedarville, Ohio.

Types.—Syntypes, nos. 19256–19260, Geological Museum, The Ohio State University.

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MANUSCRIPT RECEIVED BY THE EDITOR MARCH 18, 1942.

JOURNAL OF PALEONTOLOGY, VOL. 17, NO. 1, PP. 110–114, 13 TEXT FIGS., JANUARY, 1943

PLEISTOCENE HORSE TEETH FROM SASKATCHEWAN

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ABSTRACT—Glacial gravel near Sutherland, Saskatchewan, has yielded remains of mammals, including a number of horse teeth. Most of these can be referred to *Equus niobrarensis* Hay. Close comparisons are possible with teeth of that species from Hay Springs, Nebraska. The age of the Sutherland material is not established, but it appears to be late Wisconsin or possibly Peorian.

EMPLOYEES of the Dominion Forest Nursery Station at Sutherland, Saskatchewan, while excavating for sand a few miles to the north, obtained bones and teeth of mammals. Specimens were sent to the writer by Mr. James McLean, Superintendent of the Nursery Station, and by Professor V. A. Vigfusson, of the University of Saskatchewan. In 1940 the writer and his wife visited the site while engaged in field work under a grant from the Penrose Bequest of the Geological Society of America. The visit was under the guidance of Mr. McLean, Prof. Vigfusson, and Prof. J. W. G. MacEwan. The geology of the occurrence was discussed with Prof. F. H. Edmunds. By agreement the specimens submitted to the writer have been divided between the Royal Ontario Museum of Palaeontology and the Department of Geology, University of Saskatchewan.

The gravel pit from which the specimens were obtained lies near the southeast corner of section 25, township 37, range 5, W. 3rd. Meridian. This is 3 miles north of Sutherland railway station and 6 miles northeast of the center of Saskatoon. A photograph and geological section of the locality are shown in figure 12. The pit has been dug into the north side of a low, rounded hill rising about 15 feet above the surrounding prairie level. It is similar to a number of small hills in the vicinity, all of which are heavily studded with large glacial boulders. The section exposed in the pit (fig. 13) shows that these boulders constitute a thin capping, beneath which are 10 to 12 feet of rather uniform gravel and sand, showing bedding. The sand is of the coarse, angular, glacial type. The pebbles average about 6 inches in diameter, but boulders up to 1 foot across also occur. Very large boulders occur at the base of the gravel in places. The one seen in the photograph (fig. 12) has a diameter of 4 feet. A basal layer of sand, about 0.5 inch in thickness, has been cemented by calcareous material into a hardpan, which can be broken by the fingers. This rests abruptly upon an undetermined thickness of dark-brown till with scattered pebbles. The hardpan doubtless owes its existence to the impervious nature of the till, which suspended the ground water and concentrated evaporation at this level. Most of the fossil bones and teeth occur at the base of the sand, often within the hardpan, and sometimes resting upon the till. The large boulders at the base of the sand are said to have bones beneath them.

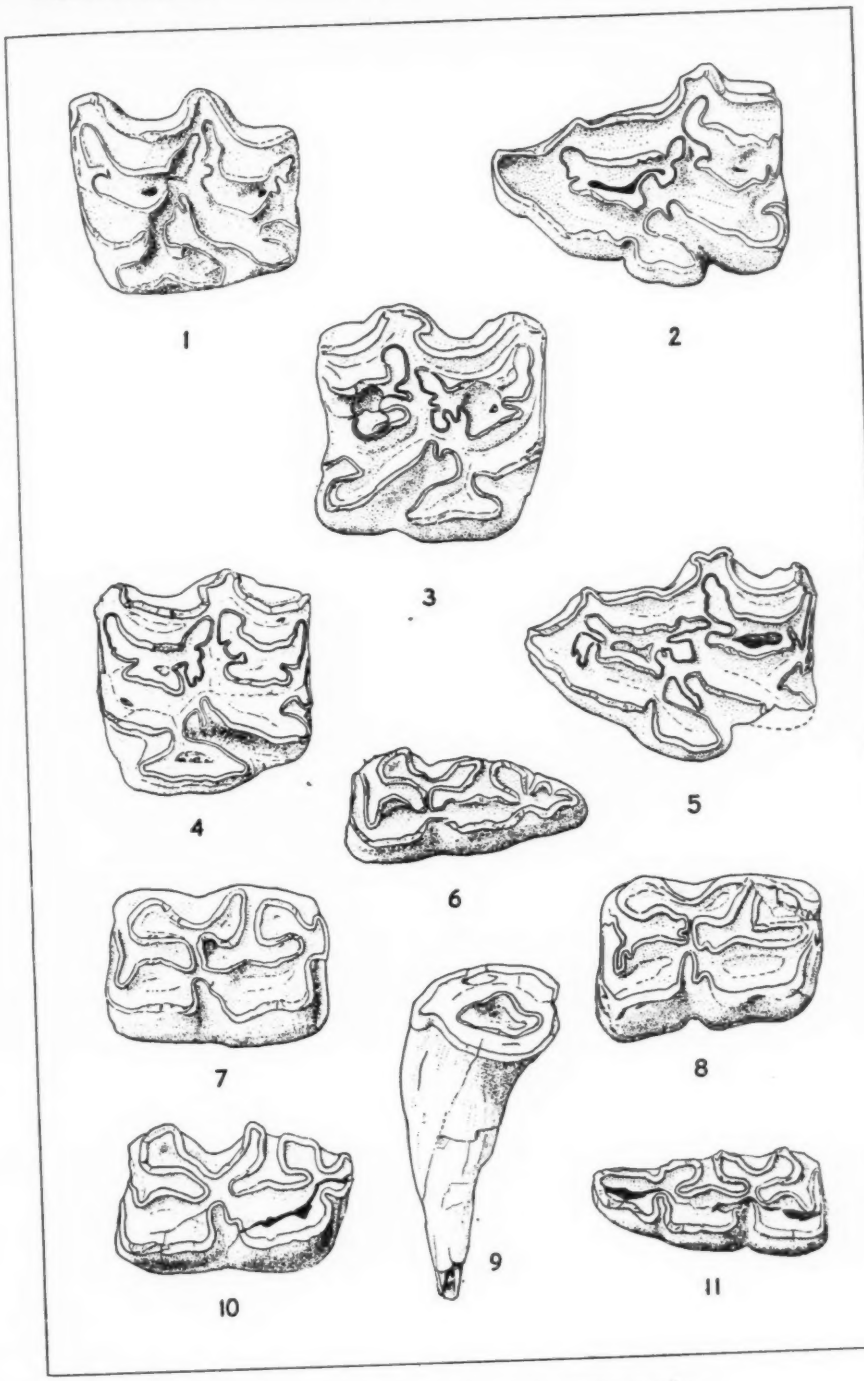
DESCRIPTION

Most of the bones from this locality are broken and water-worn. Some fragments are

EXPLANATION OF FIGURES 1–11

All figures ×1; originals in Royal Ontario Museum of Palaeontology

FIGS. *1–11.*—*Equus niobrarensis* Hay. *1*, Left M^2, No. 1328, Sutherland, Sask.; James McLean. *2*, Left P^2, No. 1329, Sutherland, Sask.; V. A. Vigfusson. *3*, Right P^3, Roy. Ont. Mus. Pal. No. 1333, identification doubtful; Sutherland, Sask.; James McLean. *4*, Left P^4, No. 1185a, identification doubtful; Hay Springs, Nebraska. *5*, Left P^2, No. 1185b, Hay Springs, Nebraska. *6*, Left M_3, No. 1330, Sutherland, Sask.; V. A. Vigfusson. *7*, Left M_2, No. 1331, Sutherland, Sask.; James McLean. *8*, Left P_4, No. 1332, Sutherland, Sask.; V. A. Vigfusson. *9*, Right I^2, No. 1334, identification doubtful; Sutherland, Sask.; V. A. Vigfusson. *10*, Left M_2, No. 1185c, Hay Springs, Nebraska. *11*, Right M_3, No. 1185d, Hay Springs, Nebraska.



FIGS. *1–11*—For explanation see opposite page.

of large size, suggesting mastodon or mammoth. Two mammoth teeth from here are in the collection of the Department of Geology, University of Saskatchewan. An occasional bison tooth is present. However, the commonest and best-preserved remains are the teeth of horses, including incisors, canines, premolars, and molars, both upper and lower. A total of 14 determinable horse teeth have been examined. A few foot bones of horse are in the collection.

FIG. *12*.—Photograph of the gravel pit north of Sutherland, Saskatchewan, August 3, 1940. The fossils occur in the sand and gravel, mostly just above the level of the pit floor. The party consists of Prof. V. A. Vigfusson, Prof. J. W. G. MacEwan, Mr. James McLean, and Mrs. Russell.

The most diagnostic data are found in the upper cheek teeth. The specimen shown in figure 1, is typical; it is apparently a left M^2. Comparisons with various fossil horses, as well as with *Equus caballus*, shows that the closest resemblances are to the corresponding tooth of *E. niobrarensis* Hay (1913). These appear in the internal indentation of the protocone, the relatively simple outline of the lakes, and especially in the shape, direction, and deep penetration of the post-protocone valley. The proportions of this tooth are similar to those of *E. niobrarensis*, but whereas M^2 of the type of that species has a length of 27 mm. and a width of 25 mm., the corresponding dimensions of the Sutherland tooth are 31.1 and 27.3 mm. The same features appear in a left P^2 (fig. 2), modified somewhat by the peculiar shape of that tooth. For example, the post-protocone valley is directed more forward than inward, but no more so than in the type of *E. niobrarensis*. The dimensions of the tooth shown in figure 2 are: length, 38.5 mm.; width, 28.4 mm. These are very close to those given by Hay for the type of *E. niobrarensis*.

The lower cheek teeth from Sutherland also show close resemblances to the corresponding teeth of *E. niobrarensis*. This shows especially in the external valley between protoconid and hypoconid, which is bifid, and, as noted by Hay, does not penetrate the space between anterior and posterior loops. Three specimens of these teeth are illustrated (figs. 6–8) for comparison with the figures given by Hay. A right I^2 is also shown (fig. 9).

There is one tooth, apparently right P^3 (fig. 3) in the Sutherland collection that shows less similarity to the typical *E. nio-*

brarensis. It is large, and almost square in outline. The protocone is but faintly indented, the postprotocone valley is directed more forward than inward, and the adjacent margins of the lakes are convoluted. It seems doubtful that this specimen represents the same species as the teeth described above.

In the Royal Ontario Museum of Palaeontology there is a series of horse teeth from the Pleistocene of Hay Springs, Nebraska, a gift of the American Museum of Natural History. Hay Springs is the locality of Hay's paratype of *E. niobrarensis*, and the teeth mentioned have been identified with that species. Four of these are here illustrated (figs. 4, 5, 10, 11). In some respects these teeth are less like the typical *E. niobrarensis* than are the majority of the Sutherland specimens. For example, the tooth shown in figure 4, probably left P^4, has an almost unindented protocone, a postprotocone valley directed more forward than inward, and lakes with complicated adjacent margins. The resemblance of this tooth to the Sutherland specimen shown in figure 3 is thus very close, and they probably both represent the same species. The left P^2 illustrated in figure 5 is typical of *E. niobrarensis*, the outline of the anterior lake being more similar to that in the type than in the Sutherland specimen shown in figure 2. In the left M_2 from Hay Springs shown in figure 10 the valley between protoconid and hypoconid penetrates the crown somewhat more than in the holotype, but no more than in Hay's paratype, also from Hay Springs (fig. 21 of Hay). The right M_3 of figure 11 differs from the holotype and from the specimen of figure 6 only in the deeply incised valley between hypoconid and hypoconulid.

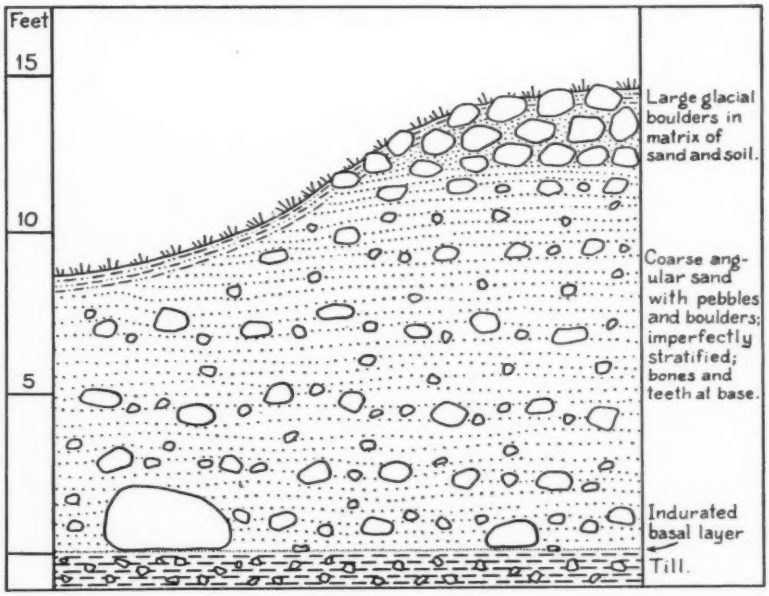


FIG. *13*.—Diagrammatic section of a part of the hill, showing the succession of sediments, and the position of the fossiliferous layer.

The writer's conclusion is that the majority of horse teeth from the Sutherland locality are referable with some confidence to *Equus niobrarensis* Hay. Such slight differences as do appear on comparison with the holotype may be matched in specimens from Hay Springs, Nebraska. One specimen from Sutherland (fig. 3) would seem to indicate a different species, but here again corresponding teeth occur in the Hay Springs collection. As far as the writer is aware, this is the first record of an extinct

species of *Equus* from Saskatchewan. In a collection of teeth and bones obtained from a bog north of Dundurn (Parks, 1925) there are numerous horse teeth not recorded by Parks. These the writer would refer to *E. caballus*. Hay (1927, p. 273) records and figures an upper molar of *E. lambei* from Empress, Albera.

GEOLOGICAL AGE

The identification of *Equus niobrarensis* among the fossils from Sutherland is not sufficient to establish the age of the deposit. Hay recorded the species as Aftonian (First Interglacial), but he was prejudiced by an hypothesis that the characteristic Pleistocene mammals of North America were confined to the early stages of that epoch. The age of the Sutherland occurrence is certainly much younger than Aftonian.

Failing a palaeontological dating, we must turn for an age determination to the geological data. Prof. F. H. Edmunds, who has done extensive work on the glacial geology of central Saskatchewan, and who is familiar with the Sutherland site, was not prepared when consulted by the writer to express a definite opinion on the age of the fossils. Under these circumstances it may be rash for the writer to attempt conclusions. Nevertheless, such an attempt will at least focus attention upon the more significant facts. Two conclusions seem reasonably justified. First, the position of the fossiliferous sands above a deposit of till indicates accumulation of the remains subsequent to a withdrawal of the glacier. That it was not very long after is suggested by the poor sorting and stratification of the sand and gravel, as well as by the angular nature of the sand grains. Probably the deposition of the material took place in or near the lake that formed in this area while the ice lay not very far to the northeast. The second conclusion is that the position of the deposits close to the present land surface, and, in fact, projecting in part above the general plain, indicates a relatively late Pleistocene age. It seems doubtful that such soft material, situated at no great depth, could survive more than one, if any, passage of the continental ice. In this connection the presence of the layer of large boulders capping the hill requires some consideration. These might be regarded as remains of a moraine formed subsequent to the deposition of the fossiliferous sand and gravel. While not prepared to disprove this view, the writer is of the opinion that the boulder layer represents a surface concentration due to erosion of sand and gravel similar to that beneath. The finer materials have been washed away, and the coarse boulders left. The group of low boulder-capped hills, of which the fossil site is one, probably owe their origin to local concentrations of boulders in the gravel. With erosion, these formed resistant caps, while the areas between, relatively more sandy, were eroded out.

The tentative conclusion of the writer, therefore, is that the fossils from Sutherland are of late Pleistocene age, dating from the time of withdrawal of the Wisconsin ice. It is possible, however, that the age is greater, but not likely more than Peorian (Fourth Interglacial).

It is highly desirable that additional work be done at the Sutherland locality. A definite geological dating would help to establish the age significance of *Equus niobrarensis*, remains of which may be expected to occur elsewhere on the Canadian plains. On the paleontological side, the discovery of more diagnostic Pleistocene species would give a fixed date to incorporate in the glacial history of central Saskatchewan. Most of the specimens obtained to date have been found by men engaged in digging gravel. Excavation by trained collectors ought to produce even better material. Such an investigation need not be restricted to the one hill from which all the fossils here considered have been derived.

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LOWER TERTIARY ATURIA FROM PALESTINE

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ABSTRACT—Some specimens of *Aturia* found in southwestern Palestine and in the vicinity of Carmel were recognized as *Aturia rovasendiana* Parona, which is known to occur in the Priabonian (upper Eocene) of Egypt, northern Italy and Hungary. This has enabled us to fix the local stratigraphy and illustrate the structural and paleogeographical relations.

AMONG THE material collected by P. Solomonica during his research in 1935 in southwestern Palestine there are some poorly preserved specimens of Aturias. These are now comprised within the collections of the Geological Department, Hebrew University, Jerusalem, and the numbers appearing in this paper refer to these collections.

These Aturias were referred to by L. Picard and P. Solomonica (1936) as "Nautilidae." Some fragments were found in the "quarry of Araq el Kharab (c. 2 km. east of Iraq el Menshiye)" in white chalky limestone, in part well stratified (p. 192). Other specimens, not mentioned in the above paper, came from Ain Kussabeh in Wadi Kussabeh, 8 km. from Tell el Hesy, or nearly 15 km. south of Iraq el Menshiye. They say that in their facies the rocks of both localities are similar to the compact chalky limestone of Beit Jibrin. The authors are not clear as to the stratigraphic position of this formation and thought that it may have represented either the overlying stratum of the whole Oligocene series or corresponded to the Beit Jibrin limestone, which is the base of or underlies the Oligocene. In their conclusions they say that

> the compact fine-grained limestone, poor in fossils, characteristic of the Beit Jebrin neighbourhood which we designate as the *Jibrin series* . . . probably belongs to the upper Eocene-lower Oligocene.

Another fragment of an *Aturia* was found by Prof. L. Picard in a quarry on Jabel el Barud near Yokneam (Tell Qaimun) a locality southeast from Carmel, on the road from Haifa to Jenin, in an indubitable Eocene formation.

The determination of Aturias involves many difficulties, one of the greatest of them being the varying morphology of the shell, corresponding to different age stages of the animal. The width and the height of the shell are especially affected. Fragments of the same species may therefore be easily mistaken for those of a different species. Another difficulty is the state of preservation, which, in the case of the Aturias, is for the most part fragmentary and more or less distorted. The relative rarity of Aturias renders this difficulty even greater.

These facts explain why only a few of the recorded species of *Aturia* are well and surely established. The others are doubtful as to specific individuality, and are based mostly on their different vertical distribution. Even the comparatively frequently recorded essentially Eocene *Aturia ziczac* (Sowerby) is not always definitely distinguished from the Miocene *A. aturia* (Basterot).

SYSTEMATIC DESCRIPTION

Although all except one of the specimens are in a poor state of preservation, it was interesting to attempt a determination of the fossils in order to elucidate the relations between the three localities and to obtain more accurate information about their stratigraphic position. We have recognized them all as *Aturia rovasendiana* Parona.

ATURIA ROVASENDIANA Parona
Text figures 1–5

Aturia rovasendiana PARONA, *1898*, Palaeontographica Italica, vol. 4, p. 156, pl. 12 (1), fig. 1; pl. 13 (2), figs. 1–3.
SACCO, *1904*, Moll. terr. terz. Piemonte, vol. 30, p. 10, pl. 2, figs. 6, 7; pl. 3, figs. 1, 2.
VOGL, *1908*, Földtani Közlöny, vol. 38, p. 649
Aturia pre-aturi Cuvillier, *1935*, Inst. Égypte Mém., t. 28, p. 73, pl. 5, figs. 16–18.

FIGS. *1–5—Aturia rovasendiana* Parona. Parts of suture line showing lateral saddle and lobe and fragment of ventral saddle. *1*, Sutures of a large specimen from Piemonte; after Parona, 1898, pl. 12, fig. 1. *2*, Suture of a small specimen from Piemonte; after Parona, 1898, pl. 13, fig. 3. *3*, Specimen from Egypt; after Cuvillier, 1935, pl. 5, fig. 17. *4*, Specimen from southern Palestine (Araq el Kharab); Hebrew Univ. collection no. 13759. *5*, Specimen from northern Palestine (Jabal el Barud, southeast of Carmel); Hebrew Univ. collection no. 13761.

Collection no. 13759.—Specimen from Araq el Kharab, east of Iraq el Menshiye. The fossil is preserved as an internal mold in white *Globigerina* chalk. It is covered by a thin film of brown limonite, and the suture lines especially are filled with this material. It is the best-preserved specimen of all the Aturias investigated.

Conch nautiloconic, sublenticular, maximum diameter of the preserved phragmocone (measured across the umbilicus) 82 mm.; altitude of the greatest chamber 53

mm., e.g. 0.65 of the whole diameter; the maximum width (near the unbilical region) about 25 mm, e.g. 0.30 of the diameter; body chamber not preserved; umbilicus closed.

One volution consists of about 12 camerae. In each suture line the following elements may be distinguished: (a) a square-shouldered straight-sided ventral saddle with a shallow secondary lobe; (b) an asymetrical tongue-shaped lateral lobe, ending in a narrow blunt-pointed projection, which is separated by a slight constriction from the broader portion; (c) a broad, rounded asymetrical lateral saddle; (d) asymmetrical lobe of the umbilical portion of the conch. The dorsal saddle is not visible. The siphuncle not preserved.

Three other fragments from the same layer and the same exposure (coll. no. 13759a) are too poorly preserved for detailed observation. Two of them are fragments of the ventral part of the conch, and the third represents only a piece of lateral impression.

Collection no. 13760.—Specimen from Bir Kussabeh in Wadi Kussabeh some 8 km. southeast of Tel el Hesi and some 15 km. south of Iraq el Menshiye: Positive and negative impression of a cast similar in preservation to that from no. 13759. The fossil is strongly compressed laterally; maximum thickness only 12 mm. Maximum diameter of the preserved phragmocone can be estimated at 90 mm. The sutures are of exactly the same shape as in the specimen from Araq el Kharab. There are no other particulars to add to the former description.

Collection no. 13761.—Specimen from Jabal el Barud near Yokneam, southeast of Carmel, on the Haifa-Jenin road. The fossil represents a fragment of 1½ chambers, of which the ventral and lateral parts are preserved. The ventral saddle, the ventral lobe, and the lateral saddle are clearly recognizable. Basing an estimate on the approximate proportions of an *Aturia* suture line, the maximum diameter of the specimen is at least 110 mm., but if the body chamber is added, the maximum diameter will attain approximately 170–180 mm.

Remarks.—The types of Parona originate from the Bartonian (lower part of Priabonian or of the upper Eocene) of Gassino in Piemonte (Italy). Sacco (1904) describes this species as follows:

> Testa discoides, transverse compressa; anfractus magis alti quam lati; latus externum strictum et convexum; umbilicus clausus; anfractuum sectio alta et stricta, subtriangula. Siphonis apertura ampla, subovalis. Septa subrara, prope umbilicum ample et regulariter versus anticam partem convexa; postea inflexa, lobum caliciformem amplum et profundum, extremitate inferiori acutum, efformantia; deinde subacute angulata; latere externe laeviter subundulato-arcuata.

The characteristic suture line with the lateral lobe ending "in a narrow bluntly pointed projection" is similar to that of *Aturia parkinsoni* (Edwards) (1849) from the London clay (Lower Eocene). Morphologically and stratigraphically *A. rovasendiana* occupies an intermediate place between the essentially Eocene (chiefly lower Eocene) *A. ziczac* and the Miocene *A. aturi.*

Parona (1898) and Sacco (1904) gave measurements of three specimens, the diameters of which are 39, 54, and 190 mm. According to them the altitude of the last whorl is 0.55, 0.59 and 0.63 times the diameter; the thickness, 0.25, 0.27 and 0.26 times the diameter.

The *Aturia rovasendiana* quoted by Vogl (1908) from the upper Eocene Piszke marl of Hungary shows similar proportions: diameter, 215 mm.; altitude of the last whorl, 62 percent of the diameter; thickness, 26 percent of the diameter. One of the fossils is thicker than all the others, but the measurements are not dated.

The *Aturia preaturi* Cuvillier (1935) from the Bartonian of Gebel Heit el Ghorab (Kibli el Ahram), some 2 km. south of Pyramids of Gizeh, is based merely on a fragment of a single specimen and is indubitably analogous with *A. rovasendiana* Parona, as can be learned from the description and photographs of the author. It is true that his specimen is thicker than those of Parona (thickness 26–27 mm. at a diameter of 60–65 mm., e.g. more than 40 percent of the diameter), but the estimated figures of Cuvillier are very rough and therefore hardly reliable and a similarly thick specimen was mentioned by Vogl from Hungary and explained as a product of sexual dimorphism.

As pointed out above, *A. rovasendiana* is

intermediate between *A. ziczac* and *A. aturi*. Among other species to which it may be compared, are *A. parkinsoni* (Edwards) (1849) from the London clay (lower Eocene), the suture line of which is very similar to that of *A. rovasendiana; A. charlesworthi* Foord (1891) from the same formation as the former; *A. felschi* Ihering (1922) from the Chilean Tertiary, which is very similar in shape and also in suture, except that the lateral lobe has not the characteristic attenuate portion; *A. basteroti* Benoist (1888) from the middle Oligocene of France, which differs from *A. rovasendiana* chiefly in the greater distance between the septa, which do not touch each other; similarly close is *A. alabamensis* (Morton) from the upper Eocene of Albama, North Carolina, Florida and Mexico (Geinitz, 1887; Miller and Furnish, 1938); *A. peruviana* Olsson (Miller and Thompson, 1937) from the upper Eocene—upper Oligocene of northwestern South America is especially close to our form (Miller and Thompson, 1937). *A. brazoensis* Stenzel (1935) from the Claiborne group (middle Eocene) of Texas has similar sutures but is considerably thicker than *A. rovasendiana*.

STRATIGRAPHIC CONCLUSIONS

Aturia rovasendiana is as yet known only from the upper Eocene. The specimens from Piemonte and from Egypt are designated as of Bartonian age, and the specimens from Hungary as of uppermost Eocene. By analogy we can attribute the same age to the Palestinian *Aturia* horizons, bearing in mind that the fossil is known from very few localities and cannot therefore be definitely assumed to be a guide fossil of the Priabonian. Nevertheless as the stratigraphic position bears out this supposition also, we may assume the lower Priabonian as the most probable age of all three *Aturia*-bearing exposures.

Picard and Solomonica (1936) have already attributed an upper Eocene to lower Oligocene age to the so-called Jibrin series in southwestern Palestine. This supposition is now apparently confirmed by the existence of *Aturia rovasendiana*. The next higher horizon indicated by the paleontological evidences is that of Stampian (middle Oligocene). The lower Oligocene (and perhaps also the higher part of the upper Eocene and the lower part of the middle Oligocene) is absent there.

In the area southeast of Carmel the presence of *Aturia rovasendiana* confirms some results of the recent geological investigations in this region (Avnimelech, 1939a, b). On a plateau above the *Aturia*-bearing quarry a fossiliferous lower Lutetian bed was found. The low position of the Priabonian *Aturia* beds in relation to the lower Lutetian beds, which lie at a higher level, is explained by a fault running between the two areas.

The existence of the upper Eocene in Palestine was proved in recent years by L. Picard (1937), who discovered *Camerina incrassata* (de La Harpe) some 10 km. north of the Yokneam quarry. The identification of the *Aturia rovasendiana* gives the second paleontological proof of the presence of this formation.

The faunal relations during the upper Eocene between Palestine and Egypt on the one hand and Northern Italy and Hungary on the other are also illustrated by the present investigation.

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PLEISTOCENE MOLLUSKS FROM MARGARITA ISLAND, VENEZUELA

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ABSTRACT—A fauna of fossil mollusks from Juan Griego, on the north shore of Margarita Island, Venezuela, is herein recorded. Eighteen species are listed, of which two are described as new. All the remaining species are known to be living in shallow warm seas today. Because of the high proportion of recent species, a Pleistocene age is suggested for the fauna.

DURING August, 1939, the writer had the opportunity of spending some time on Margarita Island, Venezuela, for the purpose of collecting Recent and fossil mollusks. The work was made possible by a grant from the Penrose Fund of the Geological Society of America. Allen L. Midyette, Jr., was the field assistant on the trip. A report concerned with the Recent mollusks and their bearing on the geological history of the island has already been published (Richards and Hummelinck, 1940) as well as a preliminary list of the fossils (Richards, 1940).

Fossiliferous Pleistocene deposits occur along the water front at the town of Juan Griego on the north side of Margarita Island. The best exposure for obtaining fossils is immediately west of the town, where the fossils occur in unconsolidated limy clay (fig. 6). The same formation extends as a consolidated limestone for several miles west along the shore of the island. Here the fossils are represented by poorly preserved casts, which can not readily be identified. The sea has been cutting into this limestone, and numerous small caves were noted along the shore. At no place observed do the Pleistocene deposits occur higher than 12 or 15 feet above the sea.

ANNOTATED LIST OF THE FAUNA FROM JUAN GRIEGO[1]

GASTROPODA

MELONGENA MELONGENA Linné

An occasional shell of this species was present in the bluff, although most of the specimens were broken. The species is widely distributed throughout the West Indies. Its northernmost record is from the Florida Keys.

MELONGENA MARGARITANA Richards, n. sp.
Figures 1, 2

Shell pyriform, solid, banded with concentric lines; in a few specimens traces of brown bands about 1.5 mm. wide are visible. Spire short, without prominent sutures; four whorls; nodulose; aperture oval-oblong; canal short and open. Columella smooth; no spines on shoulder of shell.

This form is very similar to *M. corona minor* (Sowerby), which, according to Pilsbry and Vanatta (1934) is a dwarf form inhabiting protected mud flats. It differs however by having a much less pronounced shoulder and no traces of spines whatever. Furthermore the various sutures of the spire are less conspicuous in *M. margaritana*. The opening of *M. margaritana* is more rounded than in the majority of specimens of *M. corona minor* observed, although one specimen (A.N.S.P. 76843) from Sugar Loaf Key, Florida, has an opening almost identical with *M. margaritana*.

The majority of the specimens collected at Juan Griego were approximately uniform in size. It is possible that this species represents an ecological dwarfed form of *Melongena corona* Linné; however, it seems advisable to describe it as new.

Dimensions: Holotype (ANSP 14931), length 26.5 mm.; width, 15.0 mm. Paratype (ANSP 14792), length 22.0 mm.; width, 13.0 mm.

Other paratypes in the Museo de Ciencias Naturales, Caracas, Venezuela.

[1] A set of the fossils is in the collections of the Academy of Natural Sciences. Duplicates are in the Museo de Ciencias Naturales, Caracas, Venezuela.

Locality.—Juan Griego, Margarita Island, Venezuela.
Age.—Pleistocene.

TURRITELLA VARIEGATA Linné

A few badly weathered specimens were obtained from Juan Griego. The species is widely distributed throughout the Caribbean today and has been recorded from the Pleistocene? near Cumana, Venezuela (Karsten, 1886).

NASSARIUS VIBEX Say

Very common at Juan Griego. Recorded from shallow water throughout the Caribbean Sea and as far north as New Jersey. It does not seem to have been reported from any of the Pleistocene localities in Venezuela.

CERITHIUM VARIABILE Adams

A common species from South Carolina to the Gulf of Mexico and the Caribbean Sea. Reported from the Pleistocene? of Cumana, Venezuela (Karsten, 1886). Frequent at Juan Griego.

CERITHIDEA ISOTOMA Pffeiffer.

Rare at Juan Griego. A shallow-water form reported from numerous places in the Caribbean.

MARGINELLA APICINA Menke

A common West Indian species; frequent in the bluff at Juan Griego.

MARGINELLA NIVEA Adams

Some small shells from Juan Griego are referred to this species. Reported from the Recent of Key West, Florida, and the West Indies.

MARGINELLA CHRYSOMETINA Redfield?

Some small broken shells from Juan Griego are tentatively referred to this species.

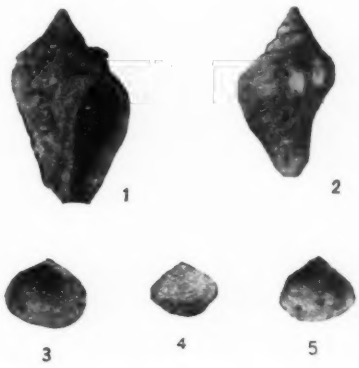
NERITINA VIRGINEA Linné

Rather frequent. Lives today in Florida and throughout the West Indies, usually in shallow brackish water.

PELECYPODA

ARCA CHEMNITZII Philippi

Shells, usually smaller than the typical *A. chemnitzii* are frequent at Juan Griego. It is not thought that the consistent small size of the shell is sufficient to establish a new variety, in as much as the Margarita



FIGS. 1, 2.—*Melongena margaritana* Richards, n. sp. *1*, Type; *2*, paratype; ×1.
3–5.—*Tellina venezuelensis* Richards, n. sp. *3*, Type; *4*, *5*, paratypes; ×1.

specimens agree in every other way with typical Recent *A. chemnitzii*. It is probable that ecological conditions determined the small size. The species is known in recent seas from Florida and Texas to the West Indies.

DONAX DENTICULATA Linné

The most common bivalve at Juan Griego. These specimens agree perfectly with living shells of this species from shallow water in the West Indies.

CORBULA CRIBARIA d'Orbigny

A few shells are referred to this species; living in the Caribbean today.

CORBULA BARRATTIANA Adams

With the above. Living today from North Carolina to the Gulf of Mexico and the West Indies from 2 to 287 fathoms.

FIG. 6.—Bluff containing Pleistocene fossils at Juan Griego, Margarita Island, Venezuela.

GEMMA GEMMA Totten

The Juan Griego specimens are slightly larger than the average Pleistocene specimens from Florida although they readily fall within the variations of Totten's species (*sensu lato*). No records known from the Caribbean, although very common in Florida waters and probably present, but unreported, from the Caribbean.

MACOMA CONSTRICTA Bruguière

Fairly common; a littoral species known today between North Carolina and Brazil.

TELLINA VENEZUELENSIS Richards, n. sp.
Figures 3–5

Shell ovate orbicular, small, thin, white, very faintly striated. Hinge nearly central with lateral tooth in one valve. Anterior side with a distinct undulation; posterior side smooth and approximately rectilinear. Pallial sinus and muscle scars indistinct.

The species is closely related and probably the ancestor of *T. mera* Say. It is consistently smaller than typical recent specimens of *T. mera*, is slightly more convex, and has a somewhat more pronounced undulation at the anterior end. Also, the shape of the anterior end of the shell is different, having a sharper angle between the edges. *T. mera*, on the other hand, is more rounded. Also, the hinge of *T. venezuelensis* is nearer the center than in *T. mera*. *T. mera* is known from the Recent and Pleistocene from South Carolina to the Bahamas.

T. tampaensis Conrad is also a related species but is relatively longer than *T. venezuelensis*.

Dimensions: Holotype (ANSP 14932), length 10.5 mm.; width, 9.0 mm. Paratypes: Academy of Natural Sciences (14806) and Museo de Ciencias Naturales in Caracas, Venezuela.

Locality.—Juan Griego, Margarita Island, Venezuela.

Age.—Pleistocene.

CHAMA sp.

Broken shells of some species of *Chama* were collected from the bluff. No perfect specimens were found.

SIGNIFICANCE OF THE FAUNA

Of the 18 species obtained from the bluff at Juan Griego, 15 are known to be living in the Caribbean Sea today. *Tellina mera* Say,

apparently the closest related species to the new *T. venezuelensis* Richards, is not known nearer than the Bahamas. *Gemma gemma* Totten has been recorded from Florida but, as far as is known, has not been collected in Venezuelan waters. *Melongena margaritana* Richards is apparently extinct and is most closely related to the recent *M. corona minor* (Sowerby) from the west coast of Florida.

As a whole, the Margarita fauna definitely suggests shallow water and perhaps even the littoral zone. The absence of deep-water species is noteworthy. The small size of the shells of *Arca chemnitzii* Philippi, *Tellina venezuelensis* Richards, and *Melongena margaritana* Richards suggests that we may be dealing with a dwarfed ecological fauna.

Fossils from Venezuela referable to the Pleistocene have been reported on several previous occasions. Martin (1888, vol. 2, p. 227–229) recorded some 23 species at Cabo Blanco near La Guaira, and Karsten (1886) listed 32 species from Colines de San Antonia near Cumana which he referred to the upper Tertiary or Quaternary. In both cases the fauna suggests somewhat more marine conditions than are indicated by the Margarita material. Liddle (1928, pp. 350–354) mentions these two localities and also records Pleistocene fossils from the Paraguana Peninsula.

AGE OF THE JUAN GRIEGO FAUNA

Because of the high proportion of Recent species (89 per cent) it is believed that the Juan Griego fauna is of Pleistocene age. Two species are extinct, although closely related to living forms. The percentage of extinct species is somewhat higher than is usual for the marine Pleistocene faunas of the Southern Atlantic and Caribbean regions. A late Pleistocene (Sangamon) age has been suggested (Richards, 1938) for the fossils from the Pleistocene of Florida. It is also probable that the fossils reported from Cuba and Cozumel Island, Mexico, date from the late Pleistocene (Richards, 1935, 1937), a fact that may account for the high proportion of Recent forms among them. It is possible that the Margarita fauna, with its slightly higher proportion of extinct forms, may represent a somewhat earlier phase of the Pleistocene. It is not thought, however, that it is as old as the Pliocene, as has been indicated on some Venezuelan maps. The absence of distinctive Pliocene species argues against this dating. That the sea covered the margins of many of the islands of the West Indies during the Pleistocene, probably during one or more of the interglacial stages of high sea level, is demonstrated throughout the entire Caribbean region. It is probable that the Juan Griego fauna represents one of these stages of high sea level.

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PALEONTOLOGICAL NOTES

LIST OF THE FOSSIL BIRDS OF NEW JERSEY

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IN THE YEARS from 1870 to 1890 New Jersey was considered a fairly good collecting ground for fossil vertebrates. During this period the marl industry reached its peak, and it was then that the fossil birds were found. Since 1890 the marl industry has declined until today only a handful of pits are being dug, and fossils, if any are being found, go unnoticed.

If collecting were done and many of the old marl pits were visited, it is almost certain that new species of fossils would be added to the New Jersey list.

Fourteen species of fossil birds have been described from New Jersey. Many are known only from New Jersey, but a few have also been found elsewhere. In this list I have tried to give all references relating to these New Jersey species that I could find.

SPECIES OF FOSSIL BIRDS FROM NEW JERSEY

Graculavus pumilus MARSH (*1872*, p. 364; SHUFELDT, *1915*, p. 19). Early Eocene, Hornerstown marl, Hornerstown. Type, Peabody Museum, Yale University.

Graculavus velox MARSH (*1872*, p. 363; SHUFELDT, *1915*, p. 17). The genotype. Early Eocene, Hornerstown marl, Hornerstown. Type, Peabody Museum.

Tympanuchus lulli SHUFELDT (*1915*, p. 69). Pleistocene, Hornerstown. Type, Peabody Museum.

Meleagris celer MARSH (*1872*, p. 261). Pleistocene, Monmouth County.

Meleagris superba COPE (*1870*, p. 239; SHUFELDT, *1915*, p. 66). (+*M. altus* MARSH, *1872*, p. 260.) Pleistocene, Monmouth County (type) and Manalapan, Monmouth County. The specimen from Manalapan is in the Peabody Museum.

Grus proavus MARSH (*1872*, p. 261). Pleistocene, Monmouth County.

Telmatornis affinis MARSH (*1870*, p. 211; SHUFELDT, *1915*, p. 27). Early Eocene, Hornerstown marl, Hornerstown. Type, Peabody Museum.

Telmatornis priscus MARSH (*1870*, p. 210; SHUFELDT, *1915*, p. 26). The genotype. Early Eocene, Hornerstown marl, Hornerstown. Type, Peabody Museum.

Telmatornis rex SHUFELDT (*1915*, p. 27). Early Eocene, Hornerstown. Type, Peabody Museum.

Barornis regens MARSH (*1894*, p. 344; SHUFELDT, *1915*, p. 35). The genotype. Eocene, Squankum, Monmouth County. Type, Peabody Museum.

Palaeotringa littoralis MARSH (*1870*, p. 208; SHUFELDT, *1915*, p. 23). The genotype. Early Eocene, Hornerstown marl, Hornerstown. Type, Peabody Museum.

Palaeotringa vagans MARSH (*1872*, p. 365; SHUFELDT, *1915*, p. 24). Early Eocene, Hornerstown marl, Hornerstown. Type, Peabody Museum.

Palaeotringa vetus MARSH (*1870*, p. 209; SHUFELDT, *1915*, p. 24). Early Eocene, Hornerstown marl, Arnytown.

Laornis edvardsianus MARSH (*1870*, p. 206; SHUFELDT, *1915*, p. 21). The genotype. Early Eocene, Hornerstown marl, near Birmingsham. Type, Peabody Museum.

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